PHYSICS
LABORATORY MANUAL

for Senior Secondary Classes

Class XII

Part 2

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CONTENTS

Themes I-V have been covered in the *Physics Laboratory Manual* for Class XII (Part I)

GANDHIJI'S TALISMAN

"I will give you a talisman. Whenever you are in doubt or when the self becomes too much with you, apply the following test :

Recall the face of the poorest and the weakest man whom you may have seen and ask yourself if the step you contemplate is going to be of any use to him. Will he gain anything by it ? Will it restore him to a control over his own life and destiny ? In other words, will it lead to Swaraj for the hungry and spiritually starving millions ?

Then you will find your doubts and your self melting away."

M K Gandhi

Solids and Semi-Conductor Devices

TOPIC I. pn JUNCTION DIODES

6.1 (Demonstration): Familiarisation of various types of pn junction diodes, junction diode, zener diode, light emitting diode (LED), photodiode and solar cell.

Components For the purpose of this demonstration, following diodes should be obtained

Three pn junction diodes (IN 4001, BY126, and OA79), three LEDs (one green, one red and one orange), two zener diodes (one of 3V and one of 5.1V breakdown voltage), one photodiode and one solar cell.

Try to distinguish these diodes by observing their shapes. In some of these diodes, a silver ring is shown on one of the ends. This end of the diode is cathode and the other anode. In some cases, the symbol of the diode is painted on the body of the diode Remember, the direction of the arrow is the direction of the current flow. Hence, the side from which the arrow starts is anode and the side towards which the arrow ends is cathode. Some diodes are bullet shaped in which case the flat side is anode and the rounded side is cathode. In the case of LED, the short lug is cathode and the long lug is anode.

The relevant technical data for some of these diodes are given in appendices.

6.2 (Experiment) : To study the forward characteristics of a pn junction diode and determine the static and dynamic resistances using the characteristics.

Components and apparatus. One diode (OA79), one half-watt resistor (0.5 kΩ), one variable voltage source (0-3V), one voltmeter (0-1V), one key and one ammeter (0-20 mA).

Procedure 1 To find the *forward characteristics* of a diode, connect the circuit as shown in Fig. 6.2 (a)

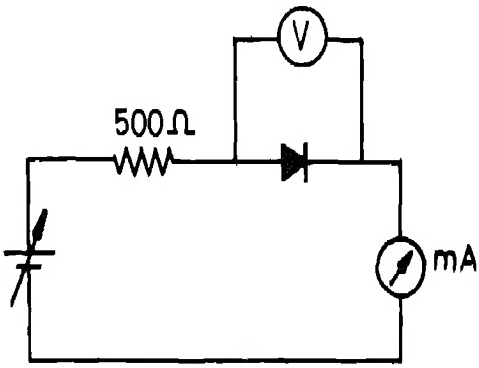


Fig 6.2 (a)

2. Start with diode voltage = 0.1V and note the current I flowing in the circuit.

3. Vary the source voltage so that you get V = 0.2V. Note the corresponding value of I. Now vary diode voltage in small steps and note V and corresponding values of I. Record the measurements in the table given below :

TABLE 6.2

V (Volt)	I (mA)	Log I	r_D (Ω)
0.1			
0.2			
.			

4. Plot a graph between V and I. You get the forward characteristics of the diode as shown in Fig. 6.2 (b).

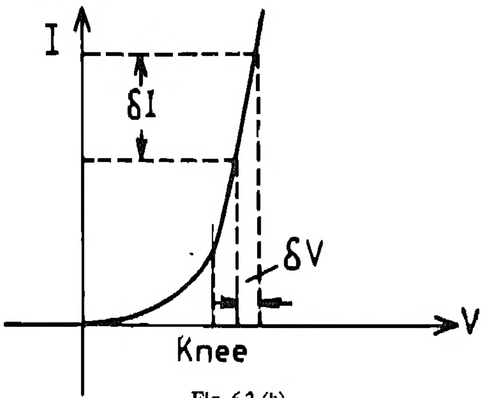


Fig 6.2 (b)

5. To find the dynamic resistance r_d of the forward biased diode, choose a small portion of the linear region of the characteristics curve (above knee voltage). Find ΔV and ΔI for this portion from the curve and calculate $r_d = \Delta V/\Delta I \Omega$ (Note, voltage is in volt and current is in ampere).

6. Find the value of static resistance r_D of the diode at several voltages on the characteristic curve. This is simply V/I.

7. Plot a graph between log I and V. This should be a straight line.

Note 1 You should not increase the value of voltage across the diode too much. Excessive current flow can damage the diode if it exceeds its limit. Maximum permissible current can be known from the technical data available.

Note 2 If a variable power supply is not available to cover 0-10V, then two dry battery cells or accumulators can be used only for forward characteristics. A rheostat or a carbon potentiometer connected in parallel with the batteries as shown in Fig 6.2 (c) give us a variable voltage source.

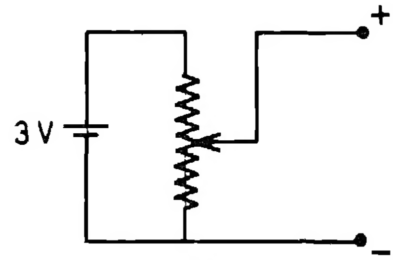


Fig 6.2 (c)

Note 3 · When you reach the knee voltage, the voltage steps may be reduced. This increases the accuracy of the characteristics curve

Note 4 If the time is available, the same experiment should be repeated with the diode BY 126. This will give you the knee point at a different voltage (Recall that the knee voltage for silicon diode is 0.7V and germanium diode is 0. 3V). Actually, for finding *I-V* characteristics, any available pn junction diode can be used. However, OA79 is being suggested simply because its reverse breakdown voltage is small compared to that belonging to other series in which case to reach the breakdown voltage, while finding out the reverse characteristics, you require a very high voltage (≈ 500 - 600 V) power supply

Note 5 · If a voltage V is applied across the junction, the total current flowing through the diode can be written as.

$$I = I_o\left(\exp\left(\frac{eV}{nk_B T}\right) - 1\right) \qquad (6.2a)$$

Where I_o is the reverse saturation current, e is the electron charge (1.6×10^{-19} C), k_B is the Boltzmann's constant (1.38×10^{-23} J/K), T is the absolute temperature and n is a constant characteristics of a material. For germanium $n = 1$ and for silicon its value is approximately equal to 2.

If the diode is forward biased, V is taken to be positive and in reverse bias it is negative At T 300 K, I comes out to be

$$I = I_o \left(\exp\left(\frac{39V}{n}\right) - 1 \right) \qquad (6.2b)$$

and when the diode is sufficiently forward biased, the unity in the bracket can be ignored. The value of n can be found out as follows using the measurements taken above

Plot a graph between log I and V for sufficiently forward biased conditions From equation (6.2b), ignoring the unity in the bracket, we get

$$\log I = \log I_o + \frac{39V}{n} \qquad (6.2c)$$

The slope of the curve (log I)/V would give $39/n$. Thus the value of n can be evaluated. Spend sometime in plotting the above graph and find the value of n and conclude whether the diode is of silicon or germanium.

6. The ideal diode equation (6.2a) shows that the magnitudes of both forward and reverse current depend on temperature The reverse saturation current I_o also depends upon temperature Actually, I_o is found to be doubled for every 10°C rise in temperature Thus, the temperature dependence of the diode current is more predominant due to I_o

The forward characteristics at room temperature have been obtained above. The same experiment can be repeated at a higher temperature of the diode which can be achieved by keeping the bit of a hot soldering iron near the diode. Plot the I-V characteristics thus obtained on the same graph paper on which the I-V curve at room temperature has been plotted Conclude your results.

You would note that the diode current increases with temperature if the diode voltage is kept constant. Conversely, if the diode current is kept constant then the diode voltage decreases with temperature

The temperature effect is more predominant in germanium diodes than in silicon diodes, since the reverse saturation current in the former is very much greater than that in the latter That is why germanium diodes are seldom used at high temperatures. The germanium diodes can withstand temperatures upto 100°C, while silicon diodes can be used up to 200°C.

6.3 (Experiment) : To study the reverse characteristics of a pn junction diode and determine the static and dynamic resistances using the characteristics.

Components and apparatus One diode (OA79), one half watt resistor (0.5 kΩ), one variable voltage source (0-50 V), one key and one ammeter (0-100μA)

Procedure 1. To find the reverse characteristics of the diode, connect the circuit as shown in Fig. 6.3 (a).

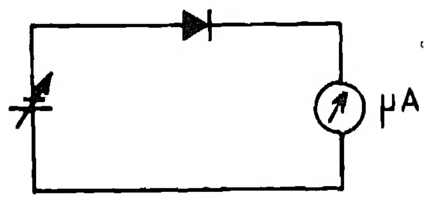


Fig. 6.3 (a)

2 Now apply voltage across the diode in steps of 2 V and note the corresponding value of I. Record the measurements in the table as given in Experiment (6 2).

3. Plot a graph between V and I. You get the reverse characteristics of the diode as shown in Fig. 6 3 (b).

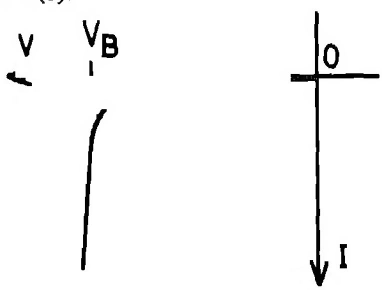


Fig 6 3 (b)

Note In this case, the diode voltage may not be measured using a voltmeter since the resistance of the diode in reverse biased condition is very high (in megaohms). The supply voltage should be treated as applied across the diode. If you have a variable voltage source upto 50 V, then you can observe the breakdown But make sure that the breakdown current should not increase the permitted limit

6.4 (Activity) : To check the condition of a diode.

Components and apparatus · The diode to be checked and a multimeter

To check the condition of a diode, measure its forward and reverse dc resistances using a multimeter as shown in Fig 6.4 (a) and (b), respectively.

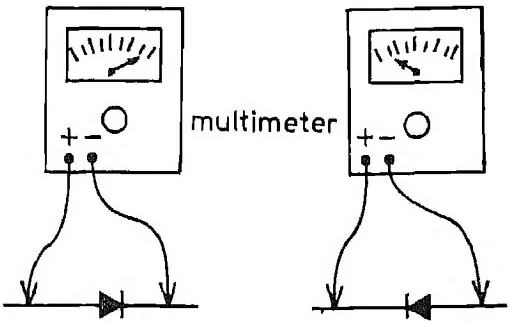


Fig 6.4 (a) Fig 6.4 (b)

If the forward dc resistance is very low and the reverse dc resistance is very high, then the diode is in working condition. If both the forward and reverse resistances are low, the diode is shorted out. If both the resistances are high, the diode is open If the reverse resistance is not sufficiently high, the diode is leaky. Avoid using low range of resistances, e g. Rx10, in the multimeter in testing the diode. Some multimeters may produce excessive current to burn out the diode. Higher scales prevent excessive current. Note also that in most multimeters when the resistance is measured, the positive terminal of the meter corresponds to the negative terminal of the internal voltage source

6.5 (Activity) : To demonstrate unidirectional property of a pn junction diode

Components and apparatus A 6V voltage source, a key, a pn junction diode and a 6 V 60 mA bulb

You have learnt that a *pn* junction diode conducts only when it is forward biased, i.e. anode is positive with respect to the cathode This unidirectional property can easily be demonstrated using the circuits shown in Fig. 6.5 (a) and 6.5 (b).

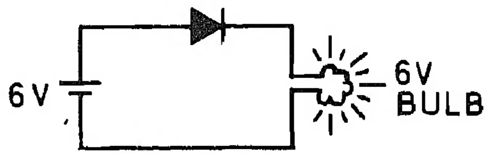


Fig 6.5 (a)

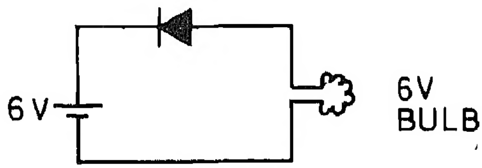


Fig 6.5 (b)

Connect the circuit as shown in Fig. 6.5 (a). When the circuit is switched on, the diode conducts as it is forward biased Therefore, the bulb glows.

Now change the polarity of the battery as in Fig 6.5 (b) The anode is negative with respect to the cathode. The diode does not conduct as it is reverse biased Therefore, the bulb does not glow This shows that the diode conducts only when the anode is positive with respect to cathode.

6.6 (Activity) : To construct a power supply with a shunt capacitor filter. (Choose your own specification).

Components and Apparatus A 6-0-6V step down transformer, two pn junction diodes IN4001, one resistor.

The unidirectional characteristics of pn junction diodes are exploited in the rectifier circuits which convert ac voltage into pulsating dc The circuit of a full wave rectifier is shown in Fig 6.6.

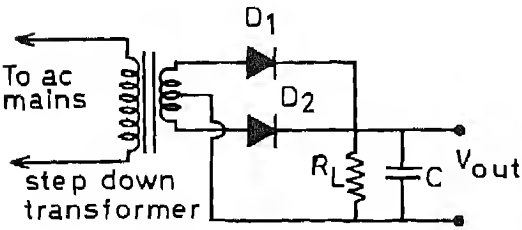


Fig 6 6

Suppose you are trying to construct a power supply with an approximate output of 7 5 V and current of 10 mA. For these specifications you require a 6-0-6 V step down transformer. Since the transformer rating is in rms values, the peak voltage available from the secondary of the transformer would be $6 \times \sqrt{2} = 8\ 4$ V.

A voltage of approximately 0 7V is dropped across the diode, so the peak value of the voltage available at the load will be $\approx$ 7.7V Therefore, a transformer of 6-0-6 V rating suits for the purpose. The current flowing in the circuit depends upon R_L. If you want 10mA current to flow, then R_L = 7 7V/10mA = 770Ω.

By connecting a capacitor of sufficiently large value, say 1000 μF, across R_L, we can smoothen the output voltage. The large value of C is choosen to make the RC time constant large compared to the time of the half cycle of the ac mains voltage With large time constant, the capacitor takes longer time to discharge. Here the capacitor charges to the peak voltage. While beyond the peak point the rectifier output decreases as rapidly as in the original ac mains voltage, the capacitor voltage drops exponentially During a certain time interval, the capacitor voltage is more than the rectifier voltage After reaching zero, the rectifier voltage rises. At a certain time, the rectifier voltage equals the capacitor voltage which is not yet fully discharged Then the capacitor charges to the rectifier voltage which increases to the peak value. This goes on. The capacitor, in this circuit, acts as a filter and reduces the variations in the output voltage The rectifier coupled with the filter is known as the power supply (The variation in the output voltage without and with the capacitor filter may be observed using a CRO as described later in demonstrations 6.22 and 6 23)

Designing a simple power supply should be undertaken as a project For this project, you require a step down centre tap transformer, two diodes IN4001, a resistor and a capacitor. Try to make a power supply with a shunt capacitor filter to give 12 V and 20 mA output (Hint. Use a9-0-9V centre tap transformer).

6.7 (Experiment): To find the characteristics of a zener diode and to determine the reverse breakdown voltage.

Components and apparatus One zener diode (3 6V), one resistor (500 Ω, 1 W), one variable voltage source (0-5V), two volt meters (0-1V and 0-5V), two milliammeters (0-100 mA and 0-10 mA), and a key

Procedure 1. Connect a circuit as shown in Fig 6.7 (a).

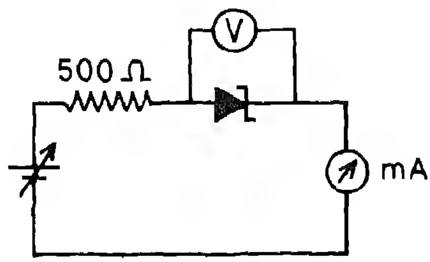


Fig. 6 7 (a)

2. Perform the experiment as in steps 2, 3 and 4 of Experiment (6 2) and obtain the forward characteristics of the zener diode. Tabulate the measurements as in that experiment

3. Now connect the circuit as shown in Fig 6.7 (b) and note I for various values of V (as in step 2 above) and plot I as a function of V to obtain

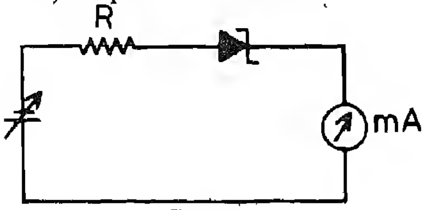


Fig. 6.7 (b)

the reverse characteristics of the zener diode. The forward and reverse characteristics would be as shown in Fig. 6.7 (c). Find the breakdown voltage V_z from the curve and calculate $R_z = V_z/I$

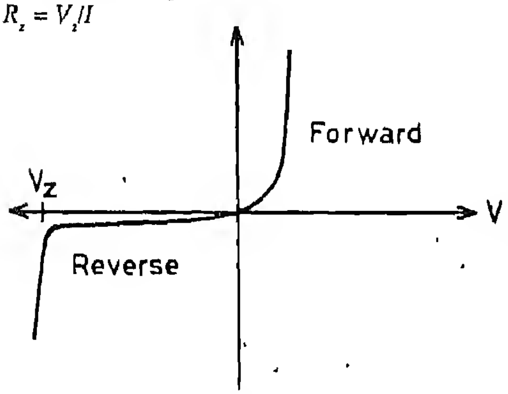


Fig 6.7 (c)

6.8 (Demonstration) : To demonstrate the use of a zener diode as a voltage regulator.

Components . A variable power supply (0-5V), a zener diode (3.6V), 500Ω resistor, a 1 kΩ carbon potentiometer and three milliammeters and a voltmeter.

Suppose, you want a regulated output of 3.6V across a load of 1 kΩ. You have a dc power supply the output voltage of which can be varied but its output is not very stable. Take a 3.6 V zener diode and connect the circuit as shown in Fig 6.8. If the power supply voltage rises, it tends to increase the V_{out}. This results in the increase in the zener current I_z. Therefore, the total current $I = I_z + I_L$ also increases. Because of the increase in the total current I, the drop across R also increases. The increase in the drop across R, with proper design, should be equal to the increase in the supply voltage V. Therefore, the V_{out} will drop to its original value. If the supply voltage decreases, then I_z also decreases resulting in the decrease in the total current. Because of the decrease in current I, the drop across R also decreases, thus maintaining the predetermined level of the V_{out}.

Now suppose that the supply voltage V is constant and the load resistance is to be varied maintaining the V_{out} to be constant. For constant supply voltage and constant V_{out}, the drop across R should be constant for which the total current I should be fixed even if the load current is varied. Assuming that I is constant, $I_z = I - I_L$. The zener diode should be so chosen that its voltage $V_z = V_{out}$. When I_L changes, the V_{out} tends to change which effects the I_z to change. The change in I_z compensates the change in I_L. Clearly, if I_L decreases, I_z increases and vice versa.

Thus the zener diode is used to give a constant voltage even if the supply voltage changes or if the load resistance is varied. The value of R can be calculated with the knowledge of V, I and V_{out} as follows $R = (V - V_{out})/I$.

Try to check the regulation using the above circuit. Take a resistance box as a variable resistor if the carbon potentiometer is not avail-

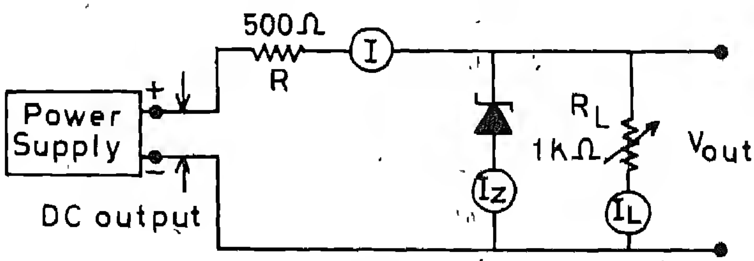


Fig 6.8

able. If you do not have a power supply, try with lead accumulators or other batteries the voltage of which can be varied using voltage divider circuit as explained earlier with Fig 6.2 (c)

Procedure . 1 Keep the load resistance constant, say 1 kΩ, and vary the supply voltage. Check whether you get a constant 3 6 V output.

2. Note the region of the supply voltage in which the constant output is available

3 Keep the supply voltage fixed so that you get the V_{out} = 3.6 V Then vary the load resistance and check whether you get a constant 3 6 V output.

4. Note the region of the load resistance in which the constant voltage is available

5. Conclude your result

By using a zener diode of appropriate voltage (as desired for your application) across the output of a power supply explained earlier in Activity (6.6), we get a regulated power supply.

6.9 (Demonstration) : To demonstrate the characteristics of a photodiode and to show that the current flowing in the circuit increases with the intensity of light incident on the photodiode.

Components and apparatus One photodiode, one voltage source (3V), one microammeter (0-100 μA), one resistor (100 Ω, 0.25 W), one key and a source of light (say a table lamp)

Procedure 1. Connect the circuit as shown in Fig 6 9. Note that the photodiode is reverse biased.

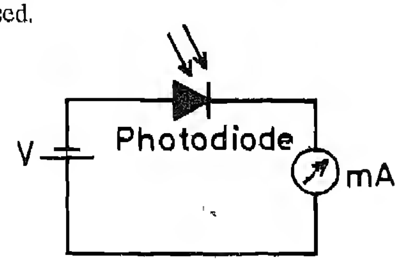


Fig. 6 9

2. Illuminate the photodiode using the table lamp You will find that the current as seen through the ammeter rises very fast and assumes high value. Now block the light using your hand, the current decreases In fact, for various positions of the hand, different values of the current are obtained depending upon the intensity of light incident on the photodiode. The experiment can be demonstrated using sun rays also.

Note. You should find the I-V characteristics (both forward and reverse) of the photodiode, as described above for a pn junction diode, in dark (i e. by covering the diode by a black paper so that no light falls on it) and in light. Illustrate your results

6.10 (Demonstration): To demonstrate the functioning of a light dependent resistor (LDR).

It is photosensitive device made of semiconductor The construction of an LDR is shown in Fig 6 10 (a)

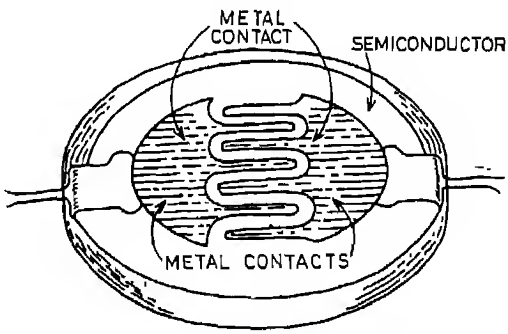


Fig 6.10 (a)

The metallic contacts are taken out from a small piece of semiconducting material (silicon). When light is made incident on it, the free electrons are generated which act as charge carriers. The larger is the number of electrons, the larger is number of charge carriers When kept in dark, or covered with hand, the resistance of the LDR is very high. As light falls on it, its resistance decreases due to the reason pointed out above.

The larger the intensity of light, the smaller is its resistance. This effect can be demonstrated using a circuit given in Fig. 6.10 (b). Cover the LDR

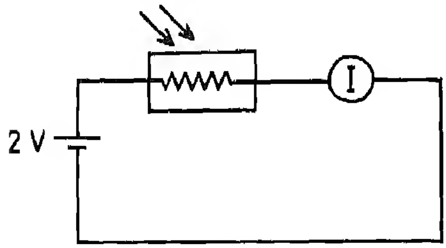


Fig 6.10 (b)

with your thumb and note the current I. Remove your thumb and note I in room light. Now take a table lamp with a regulator. Note the current I for at least four intensities of light. Calculate the value of resistance R of LDR for each measurement. Note that the resistance decreases with the increase in the intensity. If the table lamp with regulator is not available then you can perform the experiment at different places in the room, say near the window, near the room lamp, in the sun, etc.

6.11 (Demonstration): To demonstrate the characteristics of an LED and to show how intensity of its glow increases.

Components and apparatus. One LED, one resistor (200 Ω), one variable voltage source (0-5V), one ammeter (0-100 mA), one voltmeter (0-5V), and one key.

Procedure: 1. Connect the circuit as shown in Fig. 6.11. Note that the diode is forward biased.

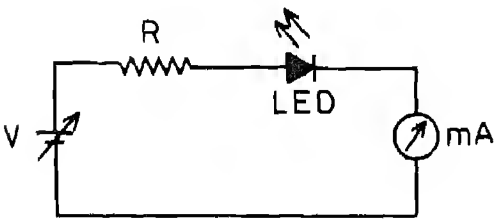


Fig. 6.11

2. Keep the diode voltage equal to 0.2V and note the value of the current I flowing in the circuit. Increase the diode voltage in steps of 0.2V and note the corresponding values of the current I and simultaneously observe the illumination.

Note that the LED starts glowing only when the voltage across it is more than 1.2V. Initially the glow is faint. However, as you increase the diode voltage V, the LED becomes brighter and brighter. Note also that when you reverse bias the LED, it does not glow.

Take some measurements as in step 3 of Experiment (6.2) so that you can plot the forward bias I-V characteristics and mention the point on the curve when the diode starts glowing.

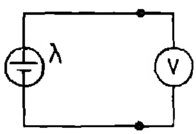
Note When using an LED as an indicator, use the following formula to determine series resistance for various voltages. $R = (V - 1.7)/I$, where R is the resistance in ohm, V is the dc voltage in volt, and I is the LED current in ampere. For I = 20 mA, it comes out that $R = 220\Omega$ for 6 V, $R = 390\Omega$ for 9 V and $R = 560\Omega$ for 12 V.

6.12 (Experiment): To find the characteristics of a solar cell for at least four values of the intensity of light incident on it.

Components and apparatus One solar cell, one table lamp with a regulator. One resistance box, one voltmeter (0-5V), and one ammeter (0-100 mA).

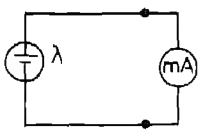
Procedure: 1 First cover the solar cell with a black paper so that it is in dark. Connect the voltmeter across it and note and record the open-circuit-voltage V_{oc} as is shown in Fig. 6.12 (a).

2. Short the terminals of the solar cell through an ammeter, Fig 6.12 (b) and note and record the short-circuit-current I_{sc}



(a)

Fig. 6.12 (a)



(b)

Fig 6.12 (b)

3. Remove the black paper. Repeat steps 1 and 2 to note and record V_{oc} and I_{ac} in the room light.

4 Then connect the circuit as shown in Fig. 6 12 (c) and note V and I in room light for at least six values of R. Tabulate the measurements taken in steps 3 and 4 as in Table 6 12

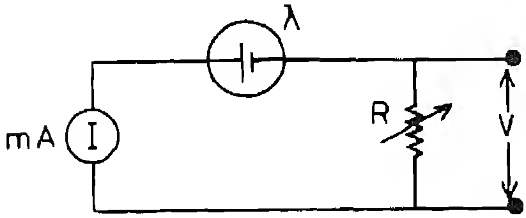


Fig 6 12 (c)

TABLE 6 12

Measurements in room light

R Ω	V mV	I mA
Open Circuit		
Short Circuit		

5. Illuminate the solar cell using the table lamp with the regulator at its minimum and repeat steps 3 and 4

6. Repeat step 5 for at least two more illuminations, say with regulator at its middle and maximum. Tabulate the measurements and conclude the result

7. Plot a graph between voltage and current for each illumination on the same graph paper You should expect the curves as shown in Fig 6.12 (d)

8. Find the point on each curve for which the power (VI) is maximum. Conclude your results. *Note:* If you do not have a table lamp with a regulator, the experiment can be done at four places, say near the window, outside the room, etc where the intensity of solar radiation will be different

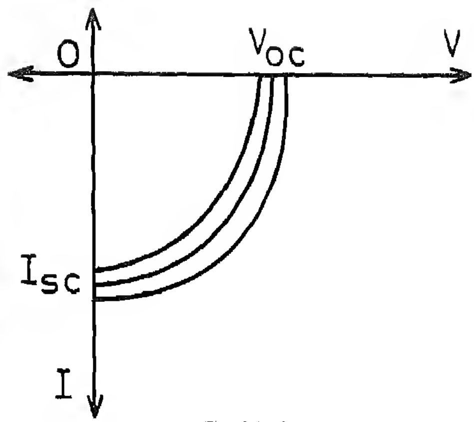


Fig 6 12 (d)

TOPIC II JUNCTION TRANSISTORS

6.13 (Demonstration) : Familiarisation of various types of transistors (audio, r.f., low power and high power).

Components one transistor each of the following numbers BC147, BC148, BC157, BC158, BF197, SL100, AC128, BF107 (Some more numbers may be added and their data should be given)

Try to distinguish these transistors by their shapes and external features Try to remember their numbers and applications Each transistor has three lugs of the same size (in general). In some transistors a dot or some mark is put on the body near one of the lugs This lug is the emitter As a matter of fact, there is no fixed rule to identify as to which lug is emitter, base or collector. You should always refer to the base diagram given in the data manual The base diagrams and the relevant technical data of some of the most common transistors are given in appendix 16.

6.14 (Experiment) : To study the characteristics of a common-emitter *npn* or *pnp* transistor and to find out the values of current and voltage gains.

Components and apparatus. One transistor BC147, two ammeters (0-100 µA and 0-20

mA), two voltameters (0-1V and 0-10V), two power supplies (0-3V and 0-10V) and two resistors.

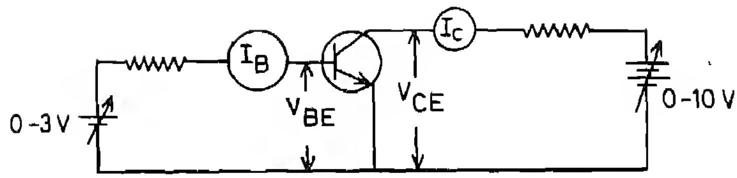


Fig 6 14 (a)

Procedure: 1. Connect the circuit as shown in Fig 6 14 (a) Note that the base-to-emitter junction is forward biased and the collector-to-base junction is reverse biased. The emitter is common to both the input and output sides of the circuit

2 To obtain the input characteristics of the transistor, keep the value of the V_{CE} fixed (say 2V) Choose V_{BE} equal to 0 1V and note I_B

3. Now keeping the value of V_{CE} fixed at 2V, vary V_{BE} in steps of 0.1V and for each value of V_{BE} note I_B Care should be taken while taking the measurements when the I_B starts increasing rapidly. Tabulate your results

TABLE 6 14 (A)

V_{BE} V	I_B mA	
	$V_{CE}=2V$	$V_{CE}=10V$

4. Repeat step 3 by keeping V_{CE} fixed at 10V

5 Plot a graph with V_{BE} on the x-axis and I_B on the y-axis Measurements obtained in step 3 and 4 should be plotted on the same graph paper

6 Conclude your results. You find that the nature of the curves obtained in step 5 is same as that of a forward biased *pn* junction diode. Further, you should notice that the effect of the V_{CE} on the characteristic curve is very marginal.

7 To obtain the *output characteristics* of the common-emitter transistor, keep the value of the I_B fixed at the lowest. Note the value of I_C as a function of V_{CE} with V_{CE} = 0, 1, 2, 3, . . . 10V Tabulate your results

TABLE 6.14 (B)

V_{CE} V	I_C mA for			
	I_{B1}	I_{B2}	. . .	I_{B6}

8 Repeat step 7 with at least six values of I_B and its highest value should be sufficiently greater than its lowest value, say at least 20 times.

9. Plot a graph with V_{CE} on the x-axis and I_C on the y-axis for one value of I_B Now plot V_{CE} vs I_C for all the values of I_B on the same graph paper. The family of curves that you get is the output characteristics of the common emitter transistor and will be as shown in Fig. 6.14 (b)

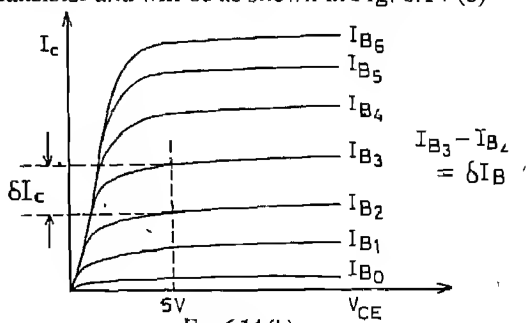


Fig 6 14 (b)

10 Conclude your results. You find that for a given value of I_B, as the V_{CE} increases the I_C first rises to a maximum value and then it becomes almost independent of the V_{CE}. Further, the value of I_C increases with the increase in the I_B

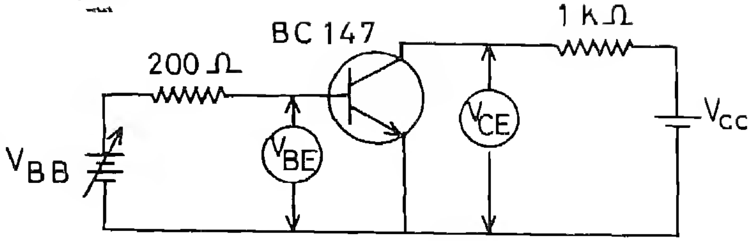


Fig. 6.15

Note The characteristics curves obtained in step 5 and step 9 are dynamic input characteristics and dynamic output characteristics of a common emitter transistor. The resistors used in the circuit are basically to control the current so as to avoid the burn-out or any damage to the transistor. If no resistor is used in the circuit and above experiment is performed, then the characteristic curves are known as the static input characteristics and static output characteristics. While obtaining the static characteristics, extra care has to be taken to avoid any damage to the transistor due to a large flow of current beyond the permissible limits.

11. Now to find the value of the current gain β (which you know is the ratio $\Delta I_C/\Delta I_B$ at constant V_{CE}) choose a value of V_{CE}, say 5V, and choose two curves corresponding to two values of I_B as shown in the Fig. 6.14 (b). At 5V points on these curves find the values of the I_C from the graph. The ratio of the difference between the two values of the I_C to the difference between the two values of the I_B gives you the value of β at V_{CE} = 5V. Find β at three values of V_{CE} by choosing curves for different values of I_B. And conclude your results.

6.15 (Experiment) : To study three modes of transistor action and to show how a transistor goes into saturation and cutoff.

Components and Apparatus One transistor BC147, one variable power supply (0-5V), one voltage source (5V fixed), two ammeters (one 0-200 μA and one 0-50 mA), two voltmeters (one 0-1V, one 0-5V) two resistors (200 Ω, and 1 kΩ).

Procedure: 1. Connect the circuit as shown in fig. 6.15. Note that the emitter is common.

2. Start from the bottom of the rheostat, i.e. when V_{BE} = 0. Since in this case the I_B = 0, therefore I_C = 0 (because $I_C = \beta I_B = 0$). Hence entire V_{CC} appears across the transistor, i.e. $V_{CE} = V_{CC}$. The transistor is in cutoff state.

3. Start increasing the value of V_{BE} in steps of 0.1 V. Emitter base junction is forward biased. And for each value of V_{BE}, note I_B, I_C and V_{CE}. Note the range in which collector-base junction remains reverse biased. When the emitter-base junction is forward biased and the collector-base junction is reverse biased, the transistor is in active mode. Note that the V_{CE} decreases with the rise in V_{BE} or I_B.

4. Increase further the value of V_{BE} and note I_B, I_C and V_{CE} and find a point beyond which $V_{BE} > V_{CE}$. In this case, both the junctions are forward biased. The transistor is in the saturation state.

5. Tabulate your results and mark the three parts of the table as cutoff, active and saturation.

6.16 (Activity) : Another variant of experiment 6.15 .

The Experiment (6.15) can be demonstrated using a circuit of Fig. 6.16.

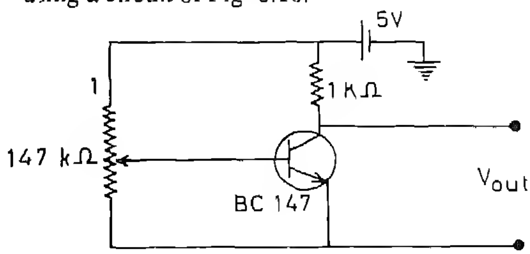


Fig 6.16

In this circuit only one power supply is used. The carbon potentiometer, 47 kΩ, acts as a po-

tential divider. The wiper of the potentiometer is connected to the base of the transistor. When the wiper goes to one end of the potentiometer which is grounded, the base voltage is zero resulting in zero base current. The transistor, in this situation, goes to cutoff and the $V_{out} = 5$ V When the wiper goes to the other end of the potentiometer that is connected to the power supply, the base voltage is very large. The transistor, in this case, goes to saturation and $V_{out} \approx 0$. When the wiper is on any position between these two extremes, the transistor is in active state. If the output of this circuit is fed to the y-input of an oscilloscope, the horizontal line can be seen to be moving from 0 position to the one which depicts 5V as you move the wiper from position 1 to position 2 of the potentiometer. In the absence of an oscilloscope, a voltmeter of 0-5V range can be connected to measure the V_{out} This circuit essentially acts as a switch and is used to make a NOT gate (described later).

This circuit neatly demonstrates that when both the junctions are forward biased the transistor goes into saturation. When the emitter-base junction is forward biased and the collector-base junction is reverse biased the transistor is in active region. When both the junctions are reverse biased, the transistor goes into cutoff. Explain how these conditions are satisfied for the three modes of operation of a transistor in this circuit. Refer to the textbook, if necessary

6.17 (Activity) : Visual display of transistor in cutoff.

You have known that if the base current I_B is zero, the collector current I_C is also zero ($\beta I_B = I_C$). For its demonstration, make a circuit as shown in Fig 6.17 using a 6V supply, a BC147 transistor, a resistor of 2.5 kW and two torch bulbs (6V, 60 mA). When the circuit is switched on, the bulb B_2 glows whereas the bulb B_1 does not. The reason is simple. The base current

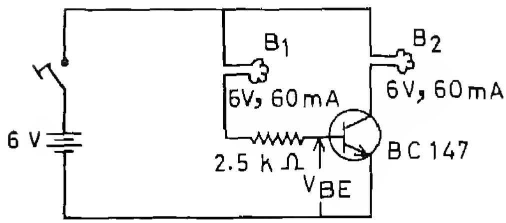


Fig 6.17

flowing through the bulb is very small and is insufficient for the bulb to glow Neglecting the emitter-base voltage, $I_B = 6V/2.5$ kW $= 2.4$ mA, and therefore, the bulb does not glow This value of current gives sufficiently large amount of collector current I_C which flows through B_2, and therefore B_2 glows. Now take out B_1 from the circuit. What happens? The bulb B_2 does not glow. Because now the base circuit is open, therefore the base current does not flow i e $I_B = 0$. Hence $I_C = 0$

6.18 (Activity) : A variant of activity 6.17 using resistance of your body.

The activity (6.17) can be repeated using an LED in series with a small resistor, 200 Ω, to avoid any damage to LED You can also have the idea of the resistance of the human body Make the circuit as shown in Fig. 6.18. When the

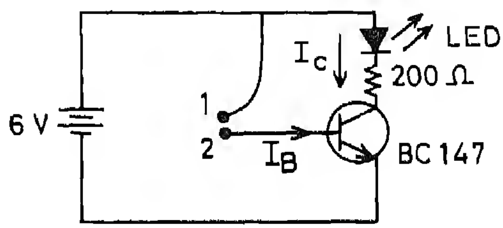


Fig. 6 18

wires 1 and 2 are not joined, $I_B = 0$ and hence $I_C = 0$. Therefore the LED does not glow. Hold the

wire in one hand and wire 2 in another. You notice the faint glow of the diode. Now hold the wires with wet hands. The diode glows but brightly. This activity demonstrates once again that when there is no base current, then there is not collector current. And also, you note that the resistance offered by the body between the dry hands is larger compared to that between the wet hands.

6.19 (Activity): A variant of activity 6.18 using an LDR.

The activity (6.18) is further modified using an LDR as shown in Fig. 6.19. When the LDR is kept in dark, i.e. when its resistance is very high, the LED does not glow. However, when light falls on it, its resistance decreases, and the LED glows. Try to explain why it so happens. (Hint: Think in which of the two situations the base current is small or the collector current is large.)

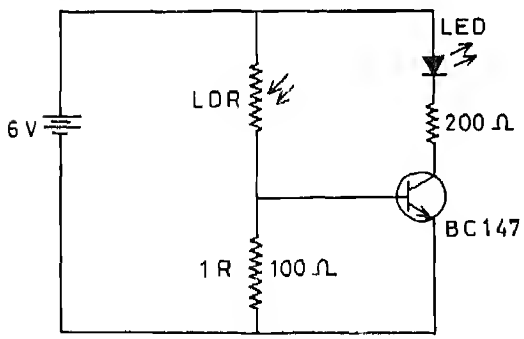


Fig. 6.19

TOPIC III: CATHODE RAY OSCILLOSCOPE

6.20 (Demonstration): Familiarisation of the working of a cathode ray oscilloscope and how ac/dc voltages are measured.

Components and apparatus: A CRO, a 6V dc battery (or a variable power supply, 0-10V), a rheostat, a dc voltmeter (0-10V), a transformer with several secondary tappings (or an audio generator), an ac voltmeter.

The cathode ray oscilloscope, or the CRO as it is often called, is a very important instrument. It enables us to exhibit the alternating voltages on its screen accurately. The analysis of most electronic circuits require the use of CRO. Therefore, its brief description and some of its applications are being illustrated here.

The CRO essentially consists of a cathode ray tube which has been described in the text-book. A specially constructed evacuated glass tube houses a cathode which is heated by a heater to emit a stream of electrons. The electron beam is focussed on to a fluorescent screen giving rise to a bright spot, the position and movement of which can be controlled externally.

The construction of a CRO is described in Fig. 6.20 (a). The cathode C is heated by the heater H whose filament is connected to the external power supply. The stream of electrons emitted by the disc-shaped anodes A_1 and A_2. The discs of the anode have holes at their centres allowing free movement of the electrons. While the potential of both the anodes with respect to cathode is high, the potential of the anode A_1 is slightly lower and variable with respect to the anode A_2. They focus electron beam on the screen and the anode A_1 acts as a focussing control. The focussing is done by A_1 and A_2 by

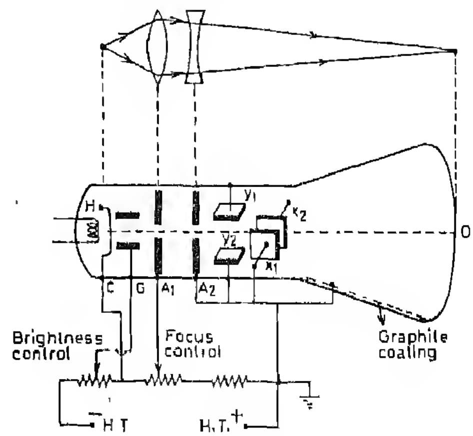


Fig. 6.20 (a)

counteracting the mutual repulsion between the electrons of the beam The anodes A_1 and A_2 act as a combination of a convex and a concave lenses as shown above the CRT in Fig 6.20 (a)

The number of electrons striking the spot area on the screen at O in a given time decides the brightness of spot. The number of electrons reaching the screen is varied and hence the brightness of the spot is controlled by a cylindrical grid G placed near the cathode and is always kept at a negative potential, which can be varied externally with respect to the cathode. The larger the negative potential on the grid with respect to the cathode, the smaller is the number of electrons reaching the screen Thus the brightness control on the CRO's front panel is essentially connected to the grid

The entire unit consisting of heater, cathode and two anodes which are responsible for producing an electron beam is called the electron gun The entire screen is coated with a fluorescent material which produces bright spot of light when the electron beam is incident on it

A power supply capable of producing a high tension of the order of 1 kV energises the electron gun. In practice, the anode A_2 which is at the highest potential is grounded so that all other potentials are negative with respect the ground The grounding of A_2 is necessary for the safe handling of the instrument and examination of the screen

To control the position of the spot externally a deflecting system is provided between the screen and the electron gun. It essentially consist of two sets of plates X_1, X_2 and Y_1, Y_2 in Fig 6.20 (a) On the application of suitable voltages they move the focussed electron beam to change its path The plates X_1, X_2 deflect the beam and hence the spot in the X-direction and the plates Y_1, Y_2 deflect the beam and hence the spot in the Y-direction. Thus with suitable voltages on X and Y plates, the spot can be obtained on any points on the screen

In general, the X-plates are associated with an electronic circuit which creates a time-base (control for which is given on the front panel of the CRO) to make the potential of plate X_2 with respect to X_1 increase linearly with time Therefore, the spot moves horizontally from left to right with a constant velocity Then the potential difference between the X_1 and X_2 is suddenly and as rapidly as possible reduced to zero resulting in the return of the spot just as rapidly to its original position This process keeps on repeating time and again.

The spot while travelling in X-direction with a constant velocity can be deflected in verticle direction if the potential difference is established between Y-plates. The verticle deflection of the spot is proportional to the applied potential difference between the y-plates. Therefore, since the spot is moving horizontally at a constant velocity, the curve traced out by the moving spot in one sweep will be of the same form as the graph of the potential difference applied to the y-plates against time. The exact repetition of the applied potential difference in the next sweep essentially depends on the speed of the time-base, i e how fast the potential difference between x-plates is reduced to zero. To obtain the repeated and steady trace of the potential difference between y-plates on the screen, the speed of the time base is adjusted by means of the frequency control which is provided on the front panel of CRO

Quiet often the steady trace does not last long and it drifts This problem is solved by injecting a small voltage applied to the y-plates into the time base circuit This is achieved by an electronic circuit, the necessary adjustment of which is done by the synchronising control (also available on the front panel). It is known as internal synchronisation. The time base circuit can be controlled externally using a signal of appropriate value. For this the CRO is switched on the external synchronisation and in this situation

internal synchronising circuit becomes inoperative. The external signal is fed to the x-input. The ac signal to be analysed is fed to the y-input.

To measure the weak signals, they are first amplified so that they can be displayed on the CRO screen. The gain of this amplifier is controlled by y-sensitivity knob. Through x- and y-shift controls small voltages are applied to obtain the steady position of the spot at any place on the screen. The CRO, thus, consists of a cathode ray tube and the entire electronic circuitry for focussing, brightness control, time base, synchronisation, etc. and supplying voltages to the electron gun and the circuit.

Now in the market, dual trace oscilloscopes are also available which are used to compare two signals simultaneously. In such oscilloscopes, the electron beam is split into two halves and are controlled by the same time base.

(i) To demonstrate the measurement of dc voltages connect the circuit as shown in Fig. 6.20 (b). Switch on the CRO and obtain a stationary spot of light by switching off the CRO time-base. Set the y-sensitivity of the CRO on an appropriate scale to measure the voltages. Apply the dc voltages in suitable steps to the y-input and in each case measure the length l of deflection of the spot OO'. And also measure the voltages using a dc voltmeter as shown in Fig. 6.20 (b). Plot a graph between the length l (on y-axis) and applied voltages V (on x-axis). You will get a straight line as shown in Fig. 6.20 (c). This means that the length of deflection of the spot is directly proportional to the applied dc voltages. The slope of the graph AB/CD gives you the deflection sensitivity in mm per volt (mmV^{-1}).

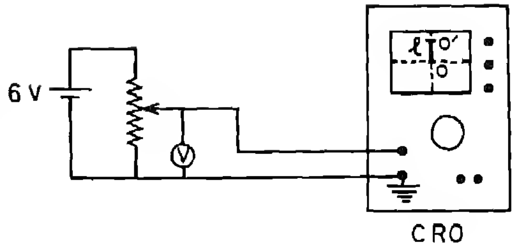


Fig. 6.20 (b)

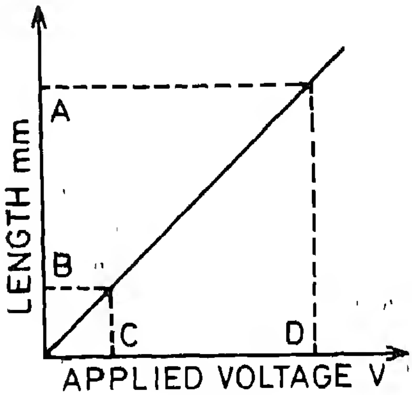


Fig. 6.20 (c)

Note: You can also use a variable power supply, if you have one, in place of the battery and its potential divider.

(ii) To demonstrate the measurement of ac voltages, connect the circuit as shown in Fig. 6.20 (d). Switch on the CRO and obtain a stationary

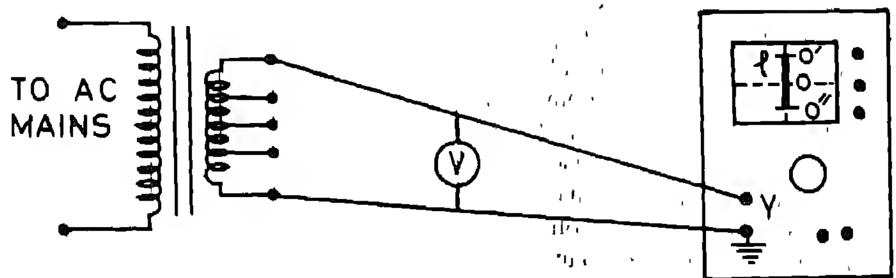


Fig. 6.20 (d)

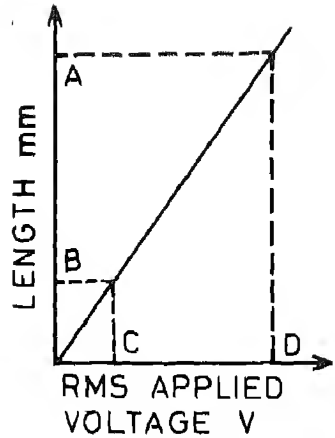


Fig. 6 20 (c)

spot of light by switching off the CRO time-base. Set the y-sensitivity of the CRO on an appropriate scale to measure the voltages Apply the ac voltages to the y-input and in each case measure the length 1 of deflection of the spot 0'0" And also measure the voltages using an ac voltmeter as shown in Fig. 6.20 (d). Plot a graph between the length 1 (on y-axis) and applied voltages (on X-axis). You will get a straight line as shown in Fig. 6.20 (c) The slope of the graph

AB/CD gives the deflection sensitivity in mm per volt Notice that it is $2\sqrt{2}$ times the deflection sensitivity obtained while measuring dc voltages. This is because (a) the spot deflection 00' and 00" are for positive and negative peaks of ac voltages (hence 1 is corresponding to twice the magnitude of peak voltage), and (b) the ac voltmeters measure rms values of the applied ac voltages.

Note: You can also use an audio generator, if you have one, in place of the transformer with several secondary tappings. The audio signal generator is an ac source of voltage. But while using it for this experiment, its frequency should be kept constant all through the experiment.

6.21 (Demonstration): To demonstrate the phase difference using a CRO.

Components and apparatus: A CRO, a resistor (1 kΩ), a capacitor (5μF), an audio signal generator.

In Chapter 8 on 'Alternating Current Circuits' of NCERT's Class XII Physics textbook, you have learnt about the phase difference between the voltage across R, C, and L when their combinations are connected to a single ac voltage source The phase difference can be demonstrated using a CRO

Connect a circuit as shown in Fig 6.21 (a) in which a signal voltage v_s is applied to the input of the RC network. This signal is also connected to the y-input of the CRO The voltage v_s-splits

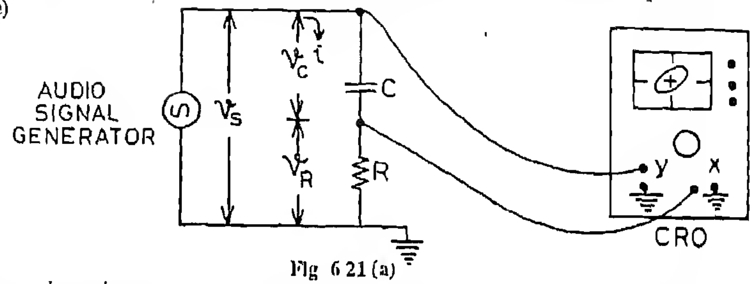


Fig 6 21 (a)

into two components. (i) v_C-across the capacitor C (lagging behind by 90° to the i flowing through it) and (ii) V_R across the resistor R (in phase with the current i) The voltage V_R is connected to the x-input. An elliptica; pattern results on the CRO screen from which the phase angle between the voltage V_R and the applied voltage V_s can be determined as shown in Fig. 6 21 (b). Find phase angle by interchanging R and C in the circuit

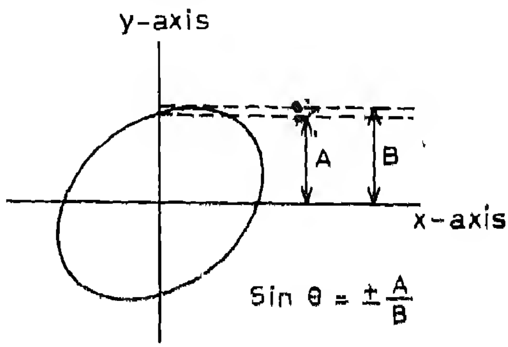


Fig. 6.21 (b)

Try to demonstrate the phase difference using various combinations of L,C, and R, and conclude your results.

6.22 (Demonstration) : To trace the output of a (i) half wave rectifier and (ii) full wave rectifier.

Components: A transformer 6-0-6 V, two diodes IN4001 a resistor 1 kΩ.

(i) Connect the circuit for the half wave rectifier as shown in Fig 6.22 (a) The centre tap is not used So the ac mains is stepped down to 12V. Choose CRO's appropriate voltage scale since you expect more than 16V as the peak output. The output across the load is fed to the y-input of the oscilloscope. You will get the rectified output of the half wave rectifier displayed on the screen. Note that every alternate half cycle is missing. Trace the pattern on a tracing paper

(ii) Connect the circuit as shown in the Fig 6.22 (b) In this case the centre tap is used, therefore the ac mains voltage is stepped down to 6V. Choose CRO's appropriate voltage scale since you expect to get more than 8V peak output. The output voltage across the load is fed to the y-input of the CRO. You will get the rectified output of the full wave rectifier displayed on the screen Note that in this case every half cycle is present. Trace the pattern on a tracing paper.

6.23 (Demonstration) : To demonstrate the use of capacitor filter with (i) half wave rectifier and (ii) full wave rectifier.

In addition to the components which are required in the previous demonstration, you need a high value electrolytic capacitor, say 1000 μF 25 V.

(i) Shunt the load resistor R of the half wave rectifier of Fig. 6.23 (a) with a 1000 μF electrolytic capacitor as shown in the Fig. 6.23 (a).

Choose CRO's appropriate voltage scale as done previously and connect the output across C to the y-input of the CRO The filtered output of

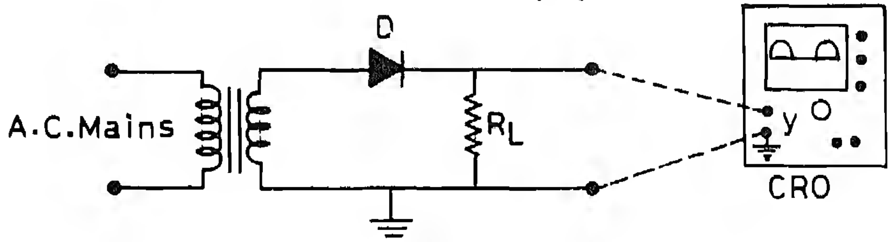


Fig 6.22 (a)

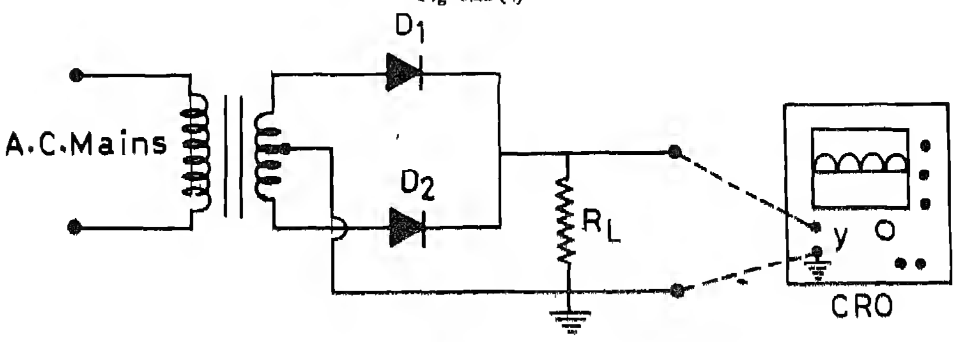


Fig. 6:22 (b)

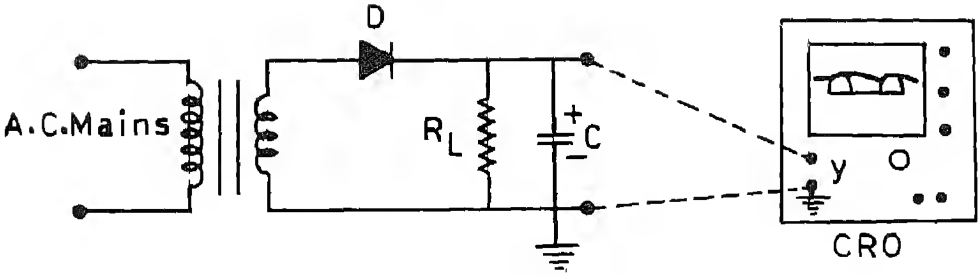


Fig. 6.23 (a)

the circuit will be displayed on the screen Trace the pattern on a tracing paper Compare this trace with that obtained in the demonstration 6 22 (i) for half wave rectifier. Notice that while the variation of voltage in the former is very small, the variation of voltage in the latter case is large Notice also that the peak voltage in both the cases remain same.

(ii) Shunt the load resistor R of the full wave rectifier of Fig. 6 22 (b) with the same capacitor as shown in Fig 6 23 (b). Choose CRO's appropriate scale and connect the output across C to the y-input of the CRO. The filtered output of the circuit will be displayed on the screen Trace the pattern on a tracing paper Compare this trace with that obtained in the previous demonstration for full wave rectifier. Compare all the four traces and conclude which one of the four traces has minimum variations in the output voltage.

6.24 (Demonstration) : To study a common-emitter amplifier and to plot a graph between gain and frequency of the signal. To explain the use of coupling capacitors.

Components A transistor BC147, 4 resistors, 3 capacitors, a power supply (10 V), and audio signal generator, an oscilloscope.

The circuit given in Fig 6.24 (a) is most commonly used as common-emitter amplifier with potential divider biasing network The resistors R_1 and R_2 act as a potential divider R_3 is the collector load resistor. The voltage applied to the base-emitter junction is the algebraic difference of voltages across R_2 and R_4 While designing an amplifier the values of these resistors have to be carefully calculated A small change in base current results in a large change in the collector current Therefore, when an ac signal is applied to the base, the voltage drop across R_4 will change due to large variations in

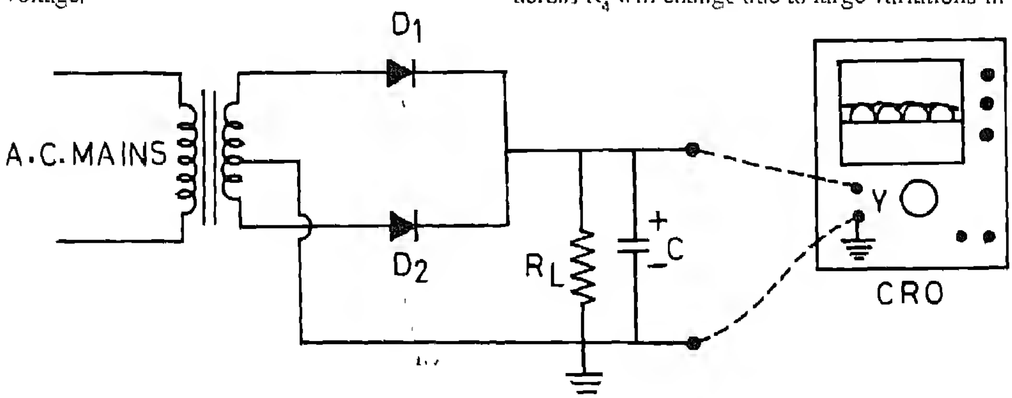


Fig 6 23 (b)

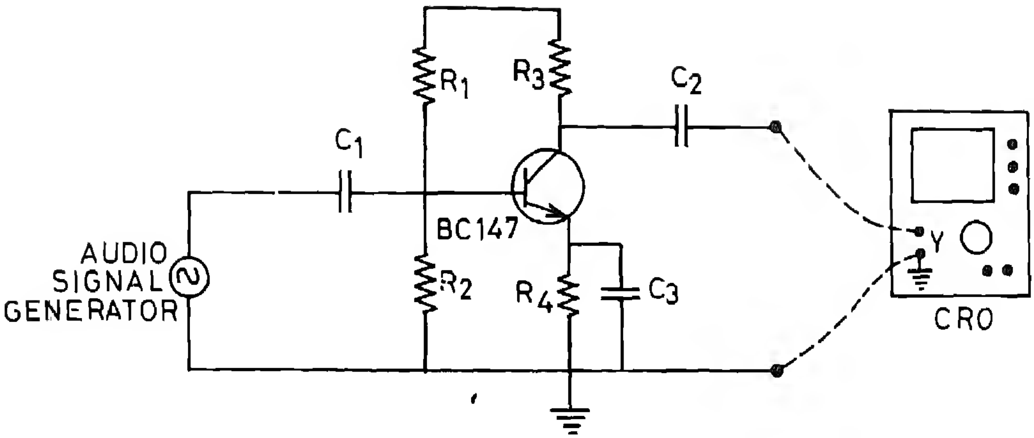


Fig. 6.24 (a)

the collector current As a result of this the emitter-base voltage changes destabilising the dc biasing of the amplifier Therefore, the resistor R_4 is shunted by a large capacitor which acts as a bypass of ac signal keeping the dc voltage drop across R_4 constant

The capacitors C_1 and C_2 are of large values so that they offer negligible impedance to ac signal and block the dc from entering the signal generator at the input and the second stage of the measuring instrument like CRO at the output

For the purpose of this demonstration, first connect the output of the audio signal generator to the y-input of the CRO which has been earlier adjusted by you to the required voltage scale Check whether you are getting the sinusoidal voltage and note the voltage of the signal. Check also whether you get fairly constant output for a wide range of frequencies. Now you should not change the output voltage of the signal generator Apply the signal voltage to the base through C_1 Note the V_{out} using CRO and calculate the voltage gain $A_v = V_{out}/V_{in}$. Repeat this step for frequencies 100 H_Z to 100 kH_Z in suitable steps Calculate gain for each measurement Tabulate the results and plot a graph between gain and the frequency. You can use a log graph paper for the purpose You will get a graph of the kind shown in Fig. 6.24 (b). Note that the gain falls at low frequencies and high frequencies regions At low frequencies the impedance of C_1 is comparatively high Therefore, some signal voltage is dropped across it resulting in the decrease in the voltage of the signal going to the base Hence, smaller V_{out} and low gain. At higher frequencies, the combined capacitance of the junctions and C_3 appear as shunt across the load. At high frequencies, their impedance is small, and this reduces the output voltage

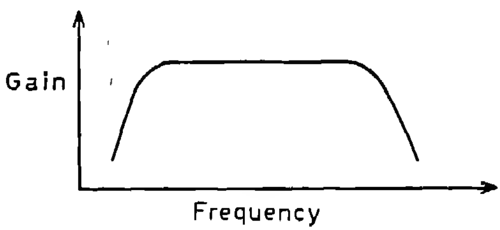


Fig 6.24 (b)

6.25 (Demonstration) : To demonstrate how the frequency of a given ac signal can be measured using a CRO.

Components and apparatus A CRO, an ac signal source frequency of which is to be deter-

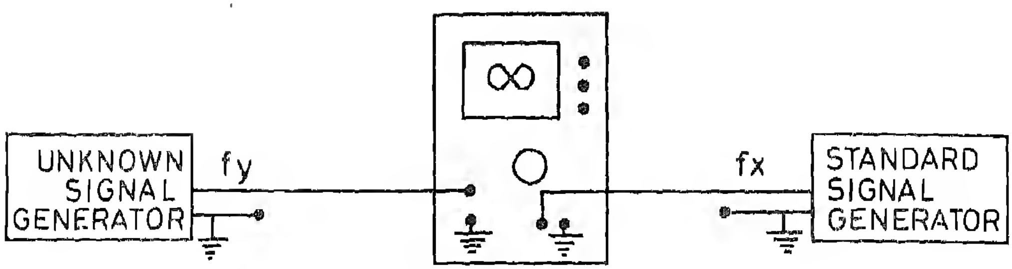


Fig. 6.25 (a)

mined (say, an oscillator), an audio signal generator

The frequency of an ac signal can be determined in two ways using a CRO. One method is the comparison method which involves one standard signal generator the frequency of which is accurately known. The other method involves the use of time-base of the CRO. Both the methods should be demonstrated.

First consider the circuit of Fig 6.25 (a) For the purpose of this demonstration, the audio signal generator can be considered as the standard the frequency of which is fairly accurately known. Let F_X be its frequency. The unknown ac signal is applied to the y-plates through the y-input and the standard signal is applied to the x-plates through the x-input. Let f_y be the frequency of the unknown signal. A pattern, called Lissajous pattern, is obtained on the screen. Note T_x, the number of points of tengency to x-axis, and T_y, the number of points of tengency to y-axis. The frequency ratio of the two signals is given by the relation.

$$\frac{f_y}{f_x} = \frac{T_x}{T_y}$$

For example, if the pattern on the screen is as shown in Fig. 6.25 (b), $T_x = 2$ and $T_y = 1$ Then, $(f_y/f_x) = 2$ or $f_y = 2f_x$. Since the frequency f_x is known, f_y can be determined.

The frequency of a signal can be determined using the time-base of the CRO. Feed the signal to the y-input. Adjust the time-base scale so that you get 3 or 4 peaks of the signal. Measure the

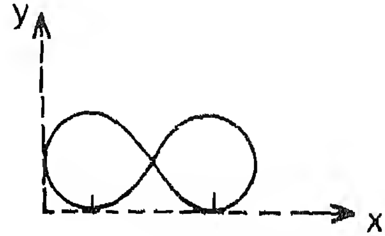


Fig 6.25 (b)

distance between the two peaks as shown in Fig 6.25 (c). Multiplying this distance by the time-

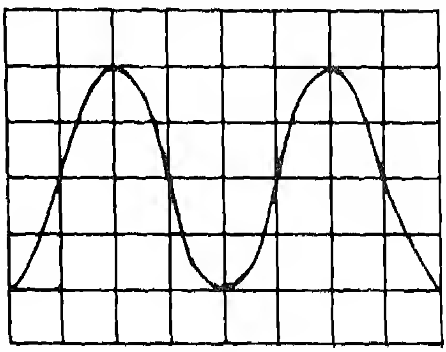


Fig. 6.25 (c)

base scale chosen earlier, you get the time-period T of the signal. And $1/T$ gives you the frequency.

TOPIC IV: DIGITAL CIRCUITS

6.26 (Experiment) : To study AND, OR and NOT gates using diodes and transistors.

Components and apparatus: Two diodes (1N4001), one transistor (BC147), two resistors

(2 of 200Ω and 1 of 1kΩ, half watt), one battery 5V, one LED.

Procedure: 1 To study OR Gate, connect the circuit as shown in Fig 6.26 (a) This gate has two inputs A and B and the output Y is observed by using the LED. As explained in the textbook, the negative of the battery, is taken as 0 and the positive is taken as 1.

2. Connect the inputs A and B to 0 Note the glow of the LED. (If the LED glows it is taken as 1 and if it does not glow then it is taken as 0) Make a table and record A, B, and Y

3. Connect A to 0 and B to 1. Note Y.

4. Connect A to 1 and B to 0. Note Y.

5. Connect both A and B to 1. Note Y

6. Tabulate the observations and see whether the truth table for OR Gate is satisfied.

7. To study AND Gate, connect the circuit as shown in Fig. 6.26(b) Note that the polarities of the diodes in this case are reverse and there is another battery of 5V connected at the output stage

8. Repeat steps 2,3,4 and 5 and tabulate your observations. Check whether the truth table for AND Gate is satisfied

9. To study NOT Gate, connect the circuit as shown in Fig. 6 26(c) Note that this circuit has a transistor rather than diodes As explained in the text book, the NOT gate cannot be realised using diodes. Further note that it has only one input.

10 Connect the input A to 0 and note Y

11 Connect the input A to 1 and note Y

12. Tabulate your observations and check whether the truth table for NOT gate is satisfied

6.27 (E) · To study NAND and NOR gates.

Components and apparatus Same as in Experiment (6.26).

Procedure 1 To study the NAND Gate, feed the output of AND gate (Fig 6 26 (b)) to the input of NOT gate (Fig 6.26(c)). This combination of the two gates is the NAND gate Then the inputs of the AND gate, i.e. A and B, are the

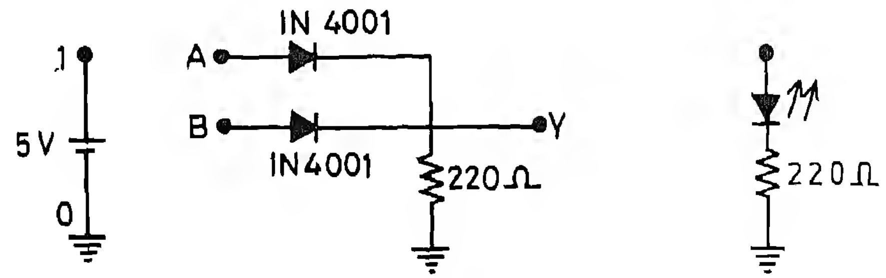


Fig. 6.26 (a)

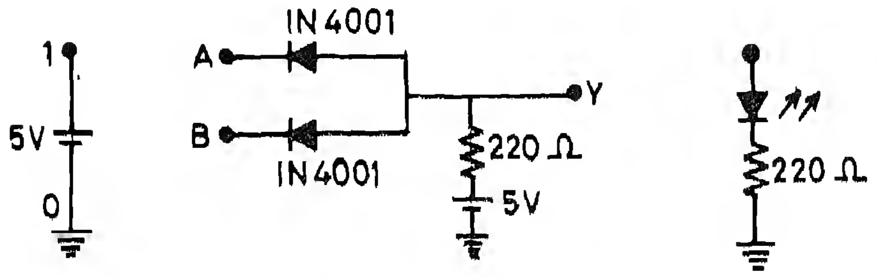


Fig. 6.26 (b)

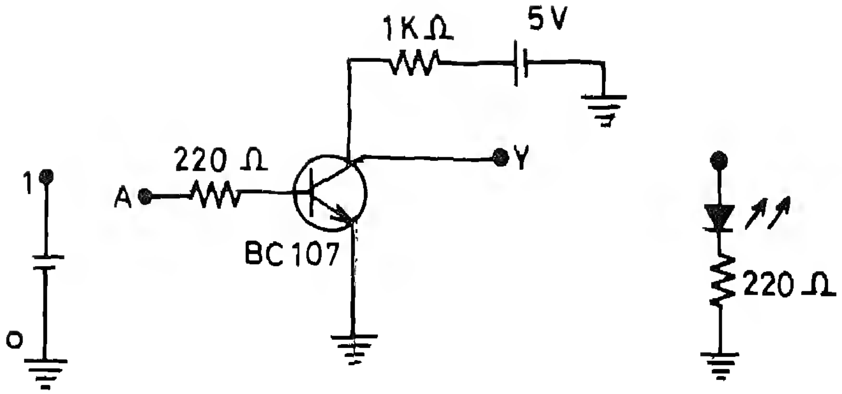


Fig 6 26 (c)

inputs of the NAND gate, and the output of the NOT gate is the output of the NAND gate Therefore, connect the circuit as shown in Fig. 6.27 (a) which is drawn using symbols of the gates

2 Repeat steps 2,3,4 and 5 of the Experiment (6 26)

3 Tabulate the observations and see whether the truth table for NAND gate is satisfied

4. To study NOR gate, you have to feed the output of OR gate (Fig. 6 26(a)) to the input of NOT gate (Fig 6.26(c)) This combination of the two gates is the NOR gate Then, the inputs of OR gate, i e A and B, are the inputs of the NOR gate, and the output of the NOT gate is the output of the NOR gate. Therefore, connect the circuit as shown in Fig 6 27(b).

5 Repeat steps 2,3,4 and 5 of Experiment (6.26).

6 Tabulate the observations and see whether the truth table for NOR gate is satisfied.

6.28 (Demonstration) : To realise different gates using NAND gates

The OR, or AND, or NOT alone cannot give a different gate by their repeated use. However, the repeated use of either NAND gates or NOR gates can give all other gates like OR, AND and NOT Hence in digital circuits NAND gate (or NOR gate) serves as a building block. The repeated use of these gates in different configuration gives various digital circuits. Although,

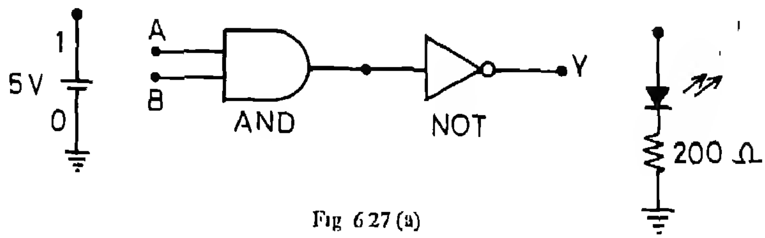


Fig 6 27 (a)

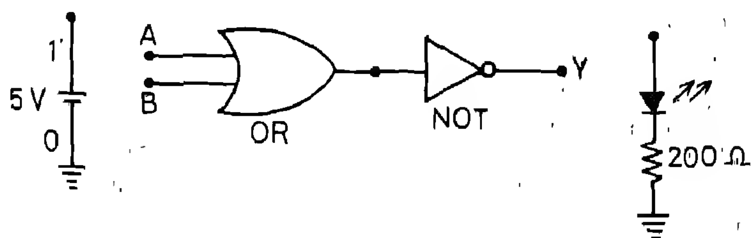


Fig. 6.27 (b)

integrated circuits (ICs) of OR, AND, and NOT gates are available in the market, but mostly the ICs of NAND or NOR gates are used In the table 6.28, the IC numbers, names of the gates, number of gates available in a single IC and the number of inputs of a gate are given. Each IC is operated at 5 volt dc.

TABLE 6 28

Number	*Name of gate*	*No of gates*	*No of inputs*
7400	NAND	4	2
7402	NOR	4	2
7404	NOT	6	1
7408	AND	4	2
7432	OR	4	2
7486	XOR	4	2

The pin diagrams are given in Fig 6.28(a) through 6.28(f) Note that the pin diagrams are the top view of the ICs (rather than the bottom view as in base diagrams of transistors) It should also be noted that it is not necessary to use all the gates of an IC simultaneously. You can use as many as you want

Before starting the demonstration, assemble carefully the ICs on the PCBs (available in the market for this purpose), each IC on a separate PCB. It is better to assemble the IC base-socket and then put the IC in it. In this way you can avoid any damage to the IC during soldering. Take out wires from the terminals of V_{cc}, GND, and inputs and output of as many gates as you want to use. Connect also an LED and a series resistor (as in Experiment 6 26) to note the output Now we can demonstrate how by the repeated use of NAND gates we can realise OR, AND and NOT gates.

Realisation of NOT Gate A NAND gate is a two input gate. If we join the two inputs to make one, then the NAND gate functions as a NOT gate. As is evident from the circuit given in Fig 6.28(g) and the truth table since A = B, we have only one input and one output just as in NOT gate

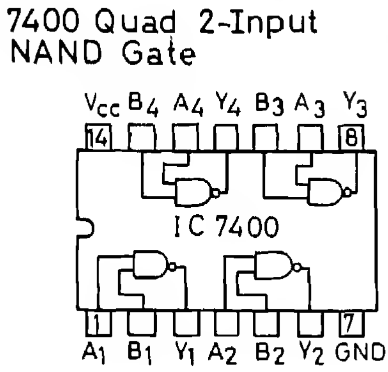


Fig 6 28 (a)

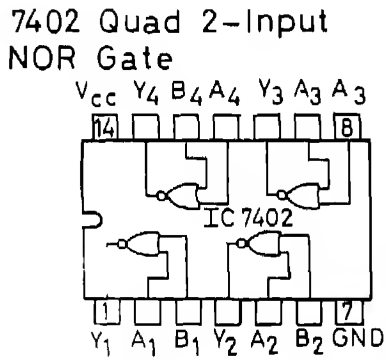


Fig. 6 28 (b)

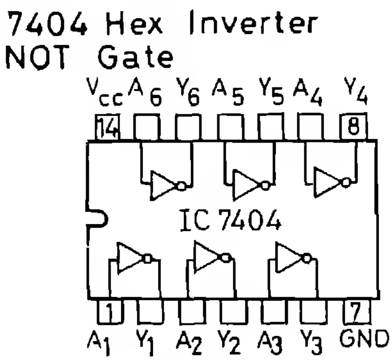


Fig 6 28 (c)

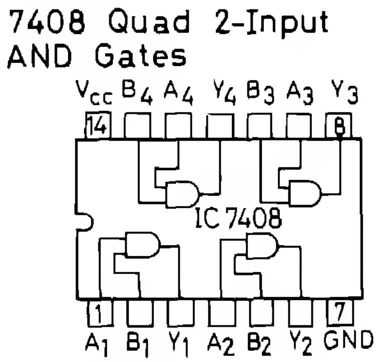


Fig 6 28 (d)

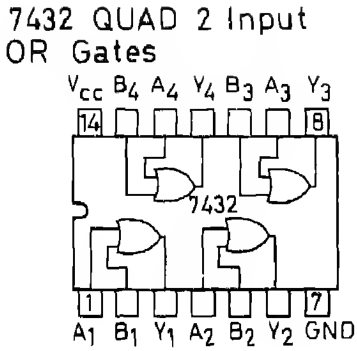


Fig 6.28 (e)

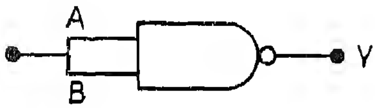


Fig. 6.28 (g)

Truth Table

A	B=A	Y
0	0	1
1	1	0

Realisation of AND gate: If we use a NOT gate after a NAND gate, then we get back AND gates as is evident from the circuit and truth table given in Fig. 6.28(h).

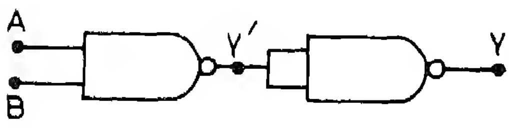


Fig. 6.28 (h)

Truth Table

A	B	Y'	Y
0	0	1	0
1	0	1	0
0	1	1	0
1	1	0	1

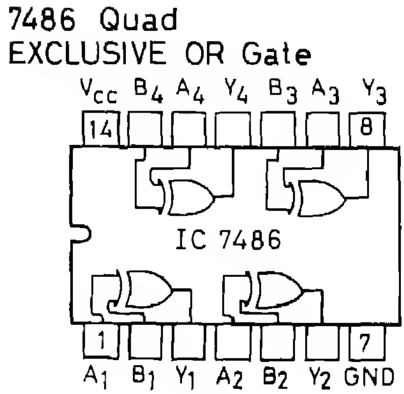


Fig. 6.28 (f)

The output Y' of NAND gate is connected to the input of NOT gate made from NAND gate to give output Y

Realisation of OR Gate: If we invert the inputs A and B before applying to NAND gate, then the output of NAND gate will be the same as of OR gate. This is evident from the circuit and the truth table given in Fig. 6.28(i). The inversion of signal can be used by using NOT gates made from NAND gates

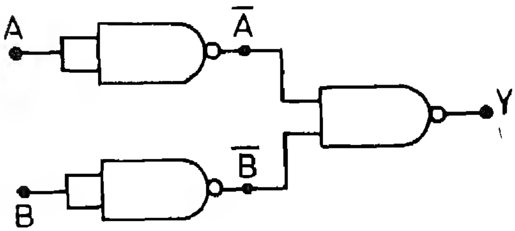


Fig. 6.28(i)

Truth Table

A	B	$\bar{A}$	$\bar{B}$	Y
0	0	1	1	0
1	0	0	1	1
0	1	1	0	1
1	1	0	0	1

6.29 (Demonstration) : To demonstrate XOR gate.

We can use NAND gates to build simple circuits for addition The most important building block for adder is XOR gate The logic symbol and truth table for an exclusive-OR (XOR) gate is shown in Fig 6.29(a) and (b) It has two inputs and one output. If inputs are A and B, then its output is expressed as $Y = A\bar{B} + \bar{A}B$.

(a) Logic symbol

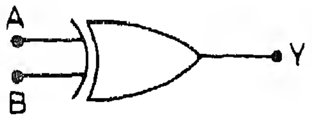


Fig 6 29 (a)

(b) Truth Table

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

(c) Circuit

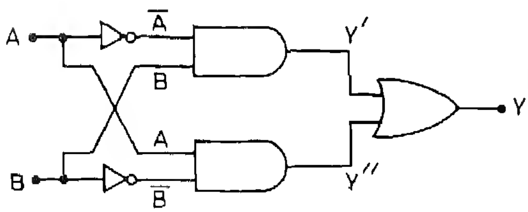


Fig. 6.29 (c)

(d) Logic Table

A	B	$\bar{A}$	$\bar{B}$	$\bar{A}B=Y'$	$A\bar{B}=Y''$	$Y'+Y''=Y$
0	0	1	1	0	0	0
0	1	1	0	1	0	1
1	0	0	1	0	1	1
1	1	0	0	0 .	0	0

Comparing truth table of XOR gate with that of OR gate, we find that in case of XOR gate output is 1 only when inputs are different. Thus a 1 in the output occurs when A or B is 1 but not both Hence, the name exclusive OR The combination of different gates can be used to make an XOR gate circuit. One simple circuit to give the XOR operation is given in Fig. 6.29(c) How this circuit performs the XOR operation is explained in Fig. 6 29(d).

6.30 (Demonstration) : To demonstrate the use of an Half Adder and a Full Adder.

You have learnt binary numbers, the conversion from binary to decimal and decimal to binary numbers, in earlier classes. We shall not go into its details, but recall a few examples to demonstrate that binary addition can give same results as decimal addition, and this can be achieved by logic gates.

A binary number is represented by two levels 0 and 1, and each digit of binary number is called a bit, the first digit is called least significant bit (lsb) and the last digit, the most significant bit (msb). For example, a three bit, binary number and its decimal equivalent is given below.

$$1\ \ 0\ \ 1 = 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0 = 5$$

msb lsb conversion to decimal Decimal number

In decimal system the addition of two one digit numbers can give a two digit number. In a similar way the addition of two one bit binary numbers gives us a two bit binary number, the first bit is designated as sum (S) which is lsb and the second as carry (C). The rules of the addition of two one bit binary numbers are given below.

0	0	1	1
+ 0	+ 1	+ 0	+ 1
00	01	01	10
CS	CS	CS	CS

You can verify that if the binary bits added are lsb, the result represents the addition of decimal number [e.g. 1+1 (binary) = $1 \times 2^0 + 1 \times 2^0$ (decimal conversion) = 2 and 10 (binary) = $1 \times 2^1 + 0 \times 2^0 = 2$].

Applying these rules we can add more than one bit binary numbers or more than two binary numbers.

The Half Adder

A circuit given in the Fig. 6.30(a) can add two one bit binary numbers A and B, and the output gives the Sum and Carry. The truth table given in Fig. 6.30(b), can be obtained by using the truth table of XOR and AND gates. You can verify that the output is addition of two decimal numbers, if two one bit binary numbers, both A and B are lsb. A two bit binary output can give the addition of up to three one bit binary numbers. The highest one bit binary is 1, and the addition of three highest one bit number 1+1 + 1 = 11 both Sum and Carry are 1

(a) Circuit

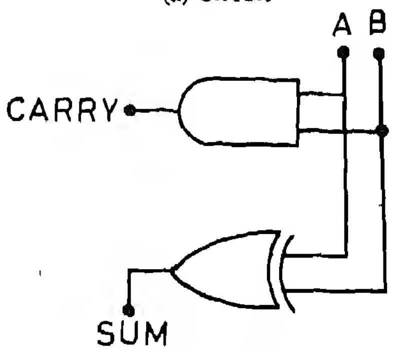


Fig. 6.30 (a)

(b) Truth Table

A	B	Carry	Sum
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

(c) Logic Symbol

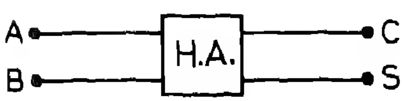


Fig. 6.30 (c)

The Full Adder

Two half adders and an OR gate as shown in the Fig. 6.30(d) can be used to add three one bit binary numbers The truth table can be obtained by using the truth tables of half adder and OR gate, and is given in Fig. 6.30(e). You can verify that by taking A,B,C as lsb and converting them to decimal numbers, their addition give correct decimal number as output when output binary number is converted into decimal number. For example, sixth row of truth table inputs are 1, 0, 1 and their addition $1+0+1 = 1 \times 2^0 + 0 \times 2^0 + 1 \times 2^{\circ}$) (decimal conversion) = 2 The output $10 = 1 \times 2^1 + 0 \times 2^0$ (decimal conversion) = 2. The circuit symbol of full adder is given in Fig 6.30(f), it has three input and two outputs. The output is the binary addition of the three one bit binary numbers.

(d) Circuit

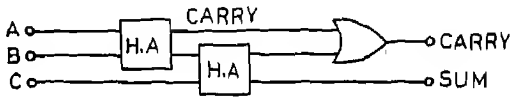


Fig 6.30 (d)

(e) Truth Table

A	B	C	Carry	Sum
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

(f) Logic Symbol

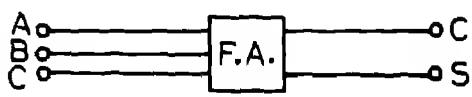


Fig. 6.30 (f)

Note The XOR gate, the half adder and the full adder should be made using the ICs which have been assembled on the PCBs. For noting the output of half and full adders, you will require two LEDs and two resistors. Remember you have already connected an LED and a resistor on each PCB.

PROJECTS

6.31 (Project) : To make a continuity tester.

Connect the circuit of a continuity tester as given in Fig 6 31 Connect the points between which the continuity is to be tested with the probes. The glow of the LED will indicate continuity

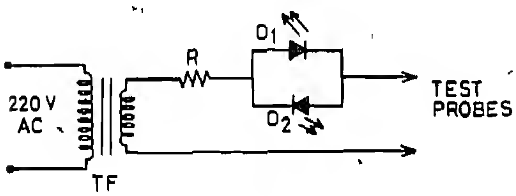


Fig. 6 31

Components

TF 220V - 6V stepdown transformer
D_1 and D_2 = LEDs
R 470 Ω, 0.25 W

6.32 (Project) : To make a multivibrator of small frequency using an IC 555.

The IC 555 is a very versatile device, mostly used in timer circuits whose characteristics can be fully controlled by external resistors and capacitor A typical multivibrator circuit is shown in Fig 6.32(a) The LED glow repeats slowly with time. The pin diagram of IC 555 is given in Fig 6 32 (b).

Components

R_1 270 kΩ, 5%, 0.25W
R_2 470 kΩ, 5%, 0.25W

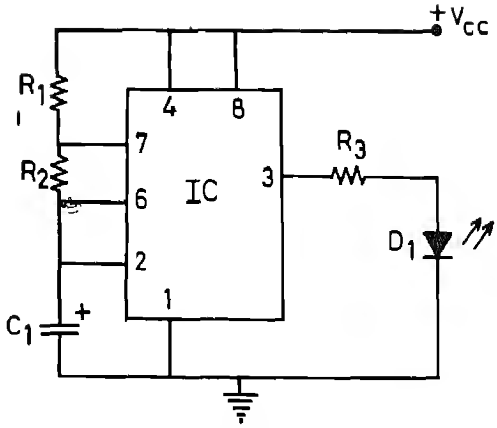


Fig 6.32 (a)

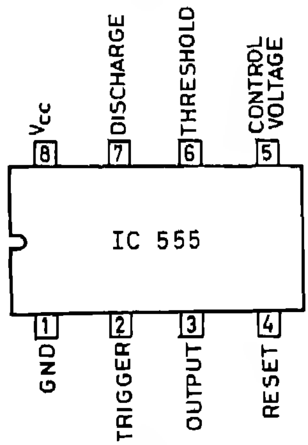


Fig. 6 32 (b)

R_3 1 kΩ, 5%, 0.25W
C_1 1.0 μF Electrolytic
Vcc + 5 to 10 V dc
IC 555

6.33 (Project) : To make a code Practice Oscillator.

The circuit for this project is given in Fig. 6.33. It is quite often used by the students to practise Morse Code for communication. Basically this circuit is also a timer circuit

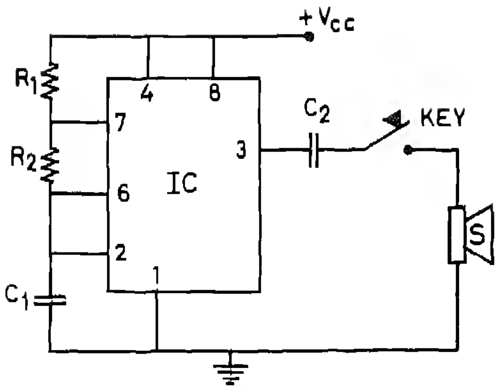


Fig. 6 33

Components

R_1	2 7 kΩ, 5%, 0 25W
R_2	5.6 kΩ, 5%, 0 25W
C_1	0.1 μF, ceramic disc type
C_2	100 μF, 16V, Electrolytic
S	8Ω, 1W, Loud speaker
IC	555
Vcc	+5 to 10V dc

6.34 (Project) · To make a flasher.

The circuit for flasher given in Fig. 6.34 is also a timer circuit based upon IC 555. The LEDs have been used as an indicator.

Components

R_1	270 kΩ, 5%, 0 25W
R_2	470 kΩ, 5%, 0 25W
C_1	1.0 μF, Polyester, or paper type
D_1	LED (Red)
D_2	LED (Red)
IC	555
Vcc	+5 to 15V dc

6.35 (Project) : To make an audio amplifier.

A typical circuit for the amplification of audio signals is given in Fig. 6 35. The signal to be amplified is fed to the input of this circuit This circuit may be used to amplify the output of a tape recorder, etc.

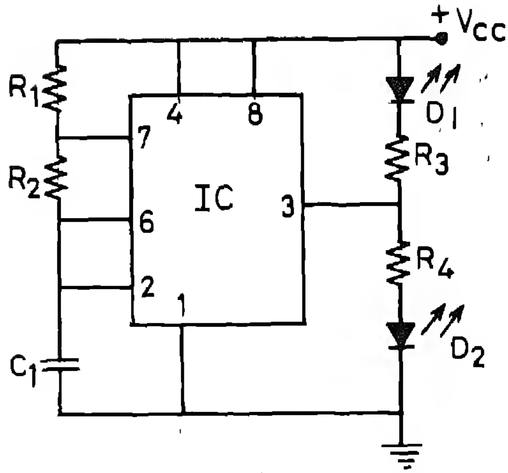


Fig. 6 34

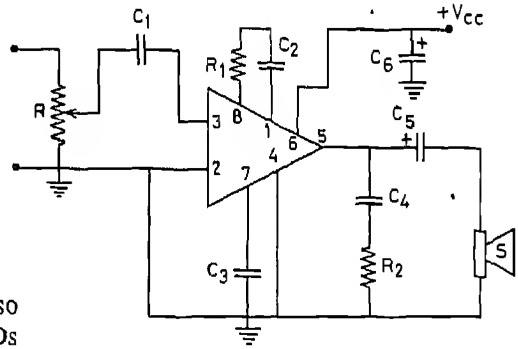


Fig. 6 35

Components

R	10 kΩ, Lin. Carbon Potentiometer
R_1	1 2 kΩ, 5%, 0.25W
R_2	10 Ω, 5%, 0.25W
C_1	10 μF
C_2	10 μF
C_3	0.1 μF
C_4	0.47 μF
C_5	250 μF, 16V, electrolytic
C_6	10 μF, 16V, electrolytic

S 8Ω, 1W, Loud speaker
IC LM 386
Vcc 5 to 15V dc

6.36 (Project) : To make a battery charger.

The circuit for a battery charger is given in Fig 6.36. The batteries to be charged are connected at B. A heat sink is used with transistor BD139 to dissipate heat, otherwise the transistor may be damaged.

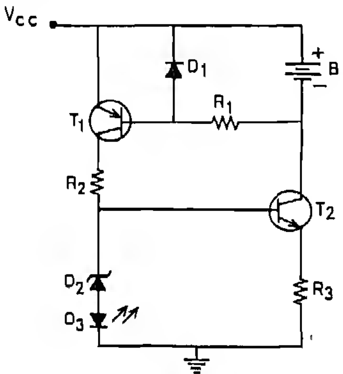


Fig. 6.36

Components

R_1	6 8 kΩ, 1/2 W
R_2	680Ω, 1W
R_3	120Ω, 1W
D_1	1N 4001
D_2	4.7V Zener
D_3	LED
T_1	BC 157
T_2	BD 139
B	Batteries to be charged
Vcc	15V dc

6.37 (Project) To make an electronic harmonium.

The circuit for an electronic harmonium which is also based on IC 555 is given in Fig. 6.37 The note select probe should be touched with any junction of the resistors for different notes. If you want to make it a little sophisticated, then connect R_1 to R_{15} junctions with press switch. The note select probe should be made a common line. When you press a switch, say R_{10}, then the corresponding note would be selected.

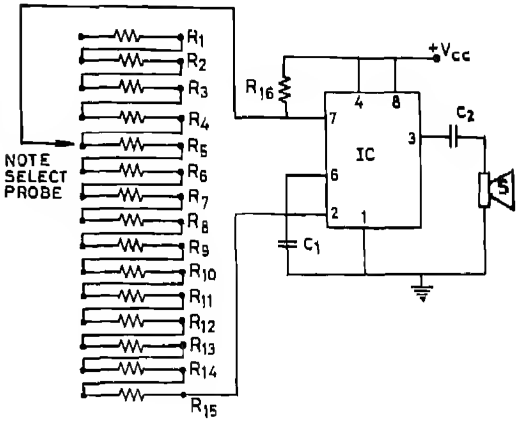


Fig 6 37

Components

R_1	82 kΩ
R_2	68 kΩ
R_3	33 kΩ
R_4	68 kΩ
R_5	47 kΩ
R_6	47 kΩ
R_7	22 kΩ
R_8	39 kΩ
R_9	33 kΩ
R_{10}	18 kΩ
R_{11}	33 kΩ
R_{12}	22 kΩ
R_{13}	22 kΩ
R_{14}	12 kΩ
R_{15}	180 kΩ
R_{16}	10 kΩ
C_1	0.002 μF, ceramic disc
C_2	100 μF, 16V
S	8Ω, Loud speaker
IC	555
Vcc	5 to 12V dc

All resistors are of 5%, 0.25W.

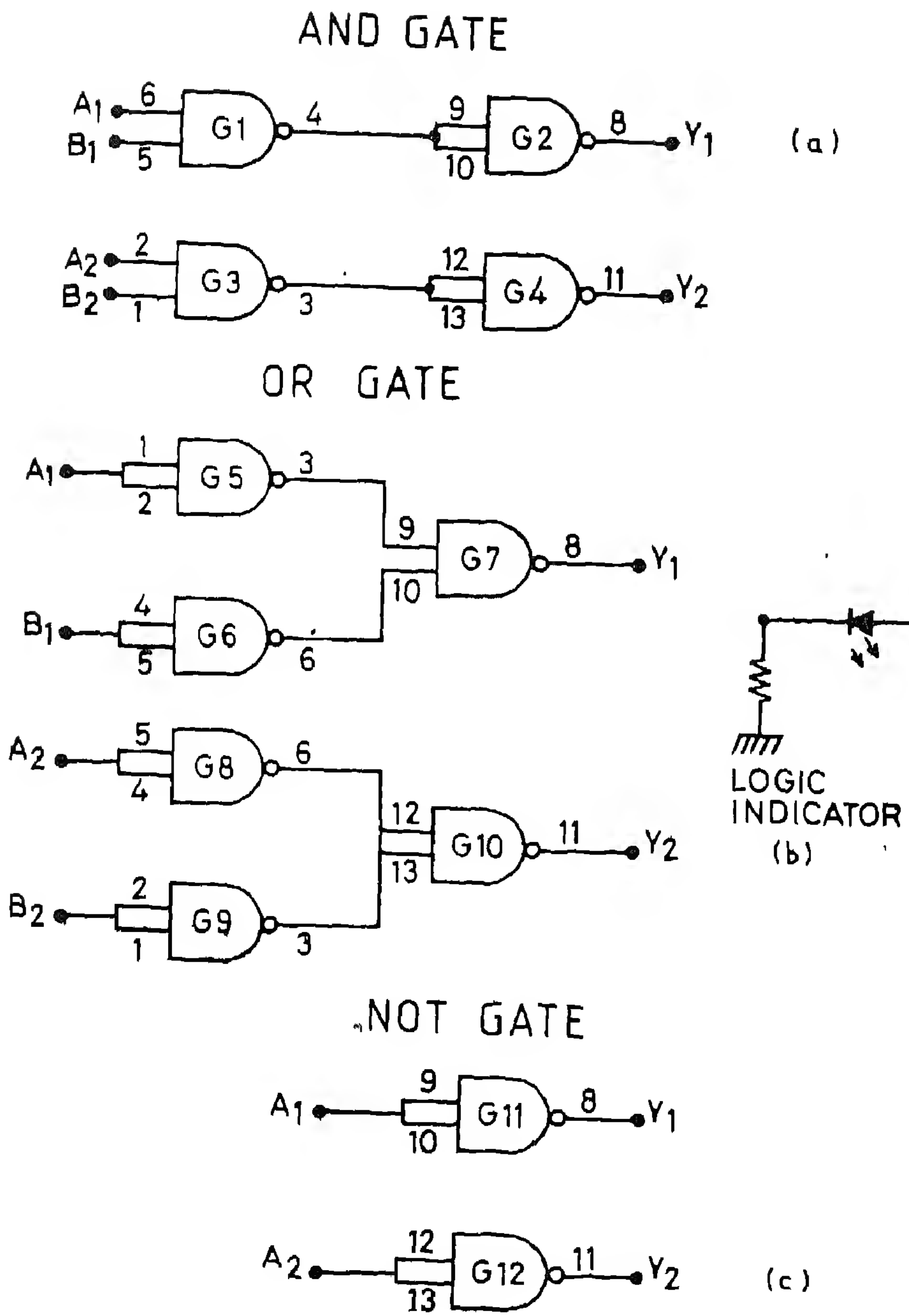

AND GATE
A1
B1
6
5
G1
4
9
10
G2
8
Y1
(a)
A2
B2
2
1
G3
3
12
13
G4
11
Y2
OR GATE
A1
1
2
G5
3
9
G7
8
Y1
10
B1
4
5
G6
6
A2
5
4
G8
6
12
G10
11
Y2
13
B2
2
1
G9
3
LOGIC
INDICATOR
(b)
NOT GATE
A1
9
10
G11
8
Y1
A2
12
13
G12
11
Y2
(c)

Fig. 6.39

6.38 (Project): To make your own kit for logic gates using discrete components.

Connect all the three circuits given in Fig. 6 26 (a), (b) and (c) on a single printed circuit board. Only one battery is needed for this project The wires from the +ve and the -ve terminals of a 5V battery should be connected to two points on a PCB Then from each of these points take out four wires Two sets of wires should be used to connect the battery in AND and NOT circuits. The rest of the two sets of wires should be used as inputs 1, 1, 0 and 0. A wire should be taken out from the output of each of OR, AND and NOT gates. This wire should be connected to the anode of the LED to note the output. Only one LED with a series resistor is sufficient.

Components

4 diodes	1N 4001
4 Resistors	220Ω, 5%, 0 25W
1 Resistor	1 kΩ, 5%, 0.25W
1 transistor	BC 147
1 LED	

6.39 (Project) : To make your own kit for logic gates using ICs.

You have already learnt from the demonstration (6.28) to realise different gates using NAND gates Take three NAND Gate ICs (No 7400) As you know, each IC has 4 NAND gates. So in total you have 12 gates. All these gates have been used to make 2 AND gates, 2 NOT gates and 2 OR gates as shown in Fig. 6.39. Here also you require only one 5V dc supply and is used to energise all the three ICs. Two wires taken out from the positive terminal and two wires from the negative terminal will serve as inputs 1, 1, 0, and 0. Only one LED with a 220 Ω series register is sufficient to be used as an indicator.

Components

3 ICs 7400
1 LED
1 Resistor 220 Ω, 5%, 0.25W

6.40 (Project): To make your own Half Adder using XOR gate and a NAND gate.

Take XOR and NAND gate ICs Each IC has 4 gates. Connect the circuit as shown in Fig 6.40. Also connect two LEDs and two series resistors to be used as indicators. Follow the method for connections as described in Project (6.39). Use it for demonstration to other students

Components

1 IC 7486
1 IC 7400
2 LEDs
2 Resistors 220 r, 5%, 0 5W

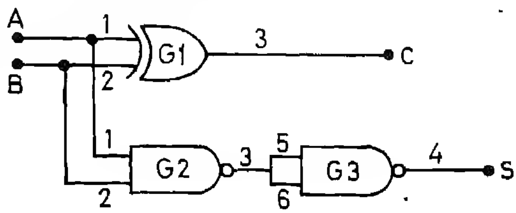


Fig. 6 40

6.41 (Project) : To make your own full adder using ICs.

Make the circuit as shown in Fig. 6 41 Demonstrate how this circuit is used as a full adder. Think of an alternative circuit You have already assembled 6 ICs on PCBs separately Try the circuit you have thought

Components

1 IC 7404
1 IC 7408
1 IC 7432
2 LEDs
2 Resisters 220Ω, 5%, 0 25W

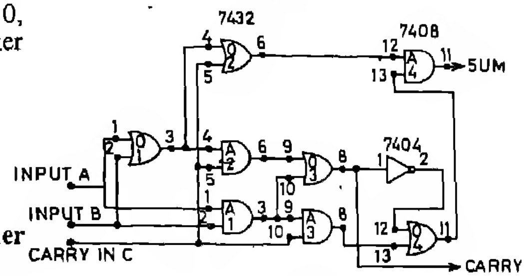


Fig. 6.41

Resistor and Capacitor Value Codes

On Resistors

The carbon resistors available in the market are very small in size and therefore it is difficult to print the value of its resistance on its body. So a colour code is printed on them in bands of different coloured paint. These bands give us the value of the resistor

To read the colour code start with the band closest to one end or if it is difficult to work out, the band farthest from the gold or silver band Consider the resistor shown in Fig. A.15(a) Let us say that the first band is brown from the table—ARC this means 1 If the second band is grey, then its value is 8 from the table. And finally if the third band is red we have a value of 2, so we add 2 zeros to the first two figures; 1, 8, and 00 or 1800 Ω.

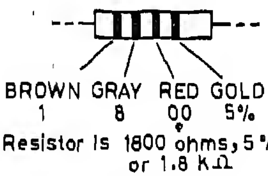


Fig. A.15(a)

The fourth or the tolerance band is gold, it means 5%. Therefore the resistor is 1800Ω ± 5% or somewhere between 1710Ω and 1890Ω. The procedure of reading a resistor is illustrated in Fig A.15 (b).

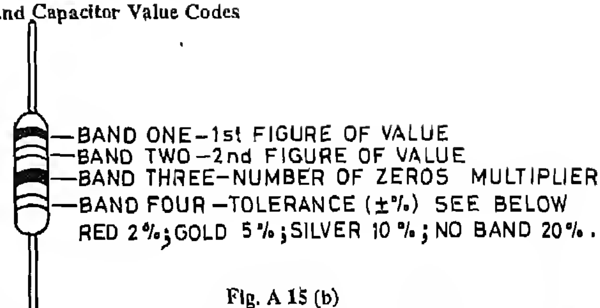


Fig. A 15 (b)

Tolerance band colours are Red 2%, gold 5%, silver 10%, and no band means 20%. The colour codes have been illustrated in Fig A.15 (c).

The resistors of all values are not available. Keeping the tolerance in mind, the system of preferred values was developed to provide a logical progression Each higher value always represents an increase by the same factor or percentage.

Preferred values for 10% resistors are as follows :

10	12	15	18	22	27	33	39
47	56	68	82				

Preferred values for 5% resistors are as follows:

10	11	12	13	15	16	18	20
22	24	27	30	33	36	39	43
47	51	56	62	68	75	82	91

On Capacitors

The capacitance values are generally printed on the body of

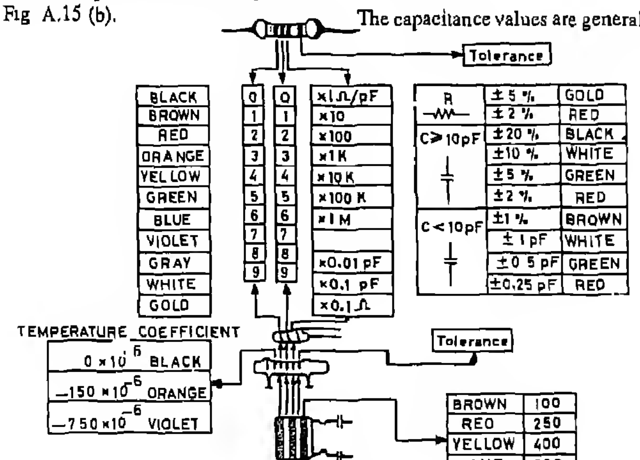


Fig. A.15(c)

the capacitors But several capacitor manufacturers use the colour code which is same as that for resistors. The method of reading the colour code is also the same. The colour code is worked out in picofarads

Some capacitor manufacturers follow a different code as is mentioned in Fig. A.15(d) In this example, the printed value is '104K' The first two figures give us 10, the third figure gives us 0000, and K stands for 10%. Therefore the value of the capacitor is 10, 00000 pF * 10% There may be another figure marked on the body This figure signifies the maximum voltage at which the capacitor can be used

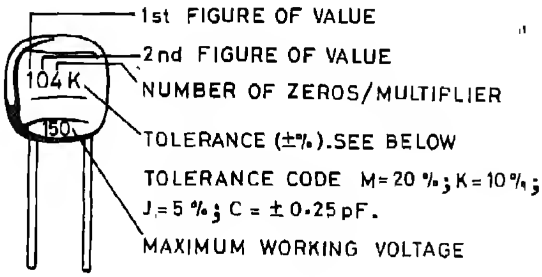


Fig A 15 (d)

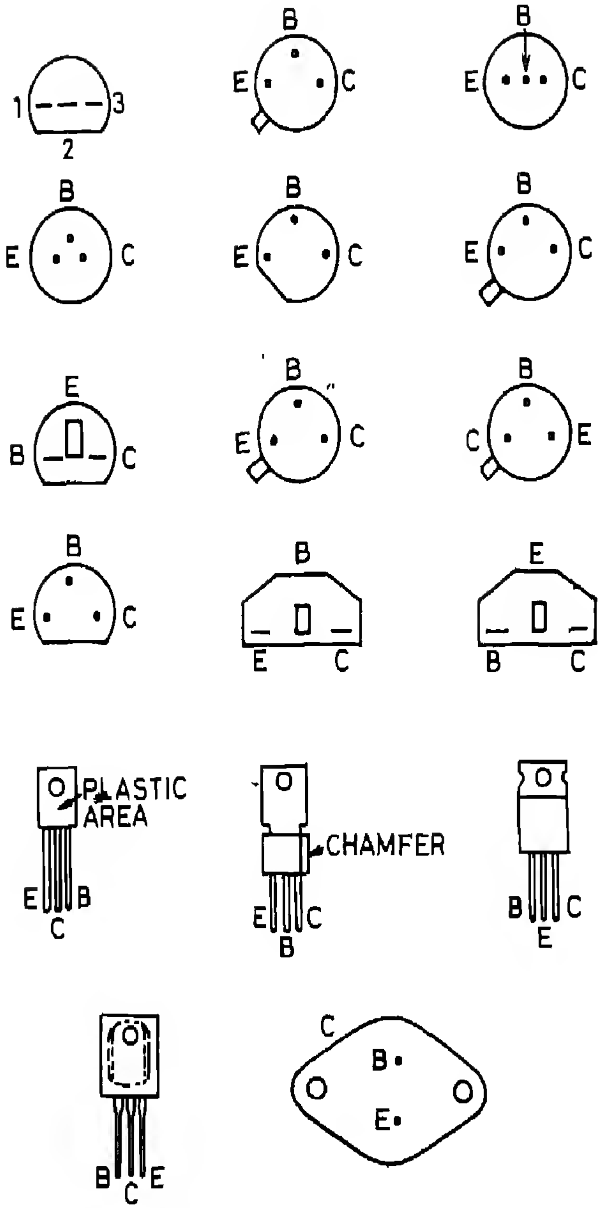


Fig A 16(a). Bottom view of some transistors. Note that the pin connections may vary with different manufacturers It is advisable to refer to the manufacturer's data sheet

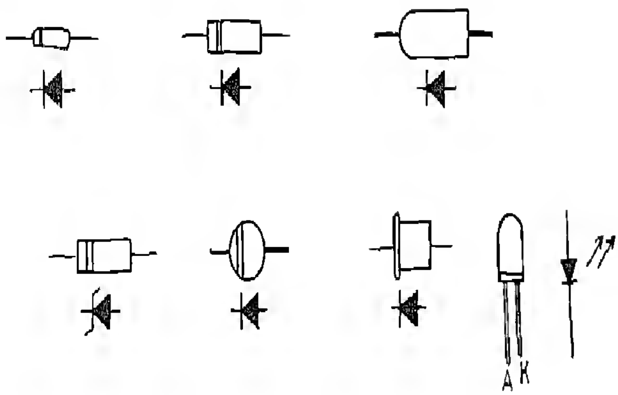


Fig A 16(b). Shapes of some diodes along with their symbols

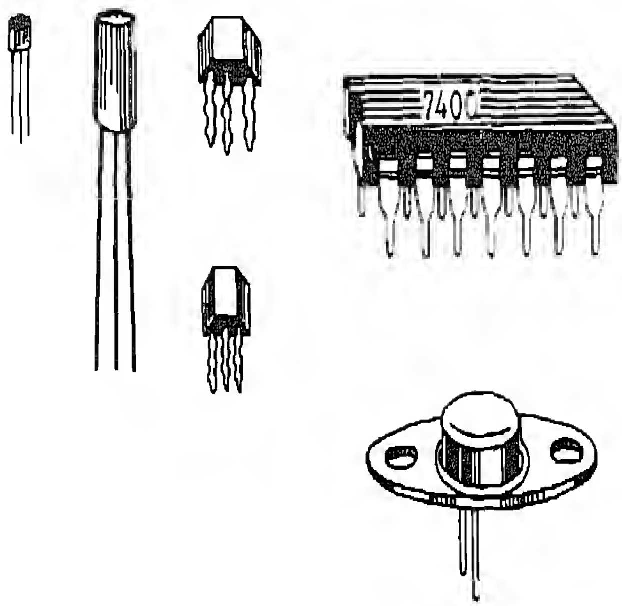


Fig. A 16(c) Shapes of some transistors and IC

APPENDIX 16

Data on Selected Solid State Components

(BEL) = Bharat Electronics Limited
(SCL) = Semiconductor Complex Limited

TABLE 1
(BEL) Germanium Diodes

Type No.	Application	Absolute max ratings @ 25°C Rev. Voltage V	Repetitive peak rev. volt V	For Current mA	Repetitive peak for cur mA	Operating amb temp °C	Forward Voltage @I_F=0.1 mA V	Reverse Current @ V_R = 1.5V uA	Diode Capacitance pF	Rectification Efficiency %	Damping resistance k Ohm	Outline
OA 70	Video detector circuits	15	22.5	50	150	−50 to +75	0.1 to 0.25	1 30	1	62	3	–
OA 72	Signal detector and Ratio detector circuits	30	45	10	100	−50 to + 60	0.2	0 8	–	85	17	–
OA 73	Video detector circuits	20	30	50	150	−50 to +75	0.1 to 0.2	1-18	1	62	3	–
OA 79	A.M. Detector and Ratio detector circuits	30	45	35	100	−50 to +60	0.15 to 0.3	0.1-2.8	–	85	15	–
OA 81	General purpose diode	90	115	50	150	−50 to + 75	0.1 to 0.25	0.3-7	–	–	–	–
OA 85	General purpose diode	90	115	50	150	−50 to + 75	0.1 to 0.25	0.4-4.5	–	–	–	–
OA 90	Video detector circuit	20	30	8	45	−55 to +75	0.1 to 0.25	2 4	–	60	2 9	DO7
OA 91	General purpose diode	90	115	50	150	−55 to +75	0.1 to 0.25	0 3-7	–	–	–	DO7
OA 95	General purpose diode	90	115	50	150	−55 to +75	0.1 to 0.25	0 4-4 5	–	–	–	DO7

TABLE 2

(BEL) Silicon Rectifiers

Type No.	Application	Absolute Max ratings @ 25°C								
		Reverse Voltage V	Repetitive Peak reverse Voltage V	Avg for current A	Surge current A	Junction Temp. °C	R_{th} J-a °C/W	Forward Voltage @I_F=5A V	Reverse Current @V_R max uA	Outline
BY 100	Mains rectifiers in T.V & Broadcast Receivers	800	1250	1 0	40	150	60	1.5	10	D 01
BY 114	Mains rectifiers in T.V. & Broadcast Receivers	450	650	1 0	40	150	60	1 5	10	D 01
BY 126	Mains rectifiers in T.V. & Broadcast Receivers	450	650	1 0	40	150	60	1 5	10	Plastic Encap-sulation
BY 127	Mains rectifiers in T.V & Broadcast Receivers	800	1250	1 0	40	150	60	1 5	10	Plastic Encap-sulation

TABLE 3
(SCL) Silicon Zener Diodes

Type No	Outline	Nominal Zener Voltage (V)	Rz Typ. @ 10mA (ohms)	P_d (W)
ESZ 4.7	TO-106	4.7	12	0.20
ESZ 5.1	TO-106	5.1	12	0.20
ESZ 5.6	TO-106	5.6	12	0.20
ESZ 6.2	TO-106	6.2	12	0.20
ESZ 6.8	TO-106	6.8	12	0.20
ESZ 7.5	TO-106	7.5	12	0.20
ESZ 8.2	TO-106	8.2	12	0.20
ESZ 9.1	TO-106	9.1	12	0.20
ESZ 10	TO-106	10	12	0.20
ESZ 11	TO-106	11	12	0.20
ESZ 12	TO-106	12	12	0.20
SZ 4.7	TO-18	4.7	12	0.33
SZ 5.1	TO-18	5.1	12	0.33
SZ 5.6	TO-18	5.6	12	0.33
SZ 6.2	TO-18	6.2	12	0.33
SZ 6.8	TO-18	6.8	12	0.33
SZ 7.5	TO-18	7.5	12	0.33
SZ 8.2	TO-18	8.2	12	0.33
SZ 9.1	TO-18	9.1	12	0.33
SZ 10	TO-18	10	12	0.33
SZ 11	TO-18	11	12	0.33
SZ 12	TO-18	12	12	0.33
TSZ 4.7	TO-5	4.7	12	0.75
TSZ 5.1	TO-5	5.1	12	0.75
TSZ 5.6	TO-5	5.6	12	0.75
TSZ 6.2	TO-5	6.2	12	0.75
TSZ 6.8	TO-5	6.8	12	0.75
TSZ 7.5	TO-5	7.5	12	0.75
TSZ 8.2	TO-5	8.2	12	0.75
TSZ 9.1	TO-5	9.1	12	0.75
TSZ 10	TO-5	10	12	0.75
TSZ 11	TO-5	11	12	0.75
TSZ 12	TO-5	12	12	0.75
TSZ 15	TO-5	15	20	0.75
TSZ 16	TO-5	16	20	0.75
PSZ 12	TO-4	12	4@100mA	10
PSZ 15	TO-4	15	4@100mA	10
PSZ 16	TO-4	16	4@100mA	10

ESZ, SZ and TSZ types are available in ± 5% tolerance
PSZ types are available in ± 10% tolerance

TABLE 4

(BEL) Low Frequency Silicon Transistors

Type No	Application	Encapsulation	Structure P-PNP N-NPN	Max coll Diss in free air at 25°C Pc (mW)	f_T Mc	Derate in free air C/mw	Absolute max rating @ 25°C BV CBO V	BV CEO V	BV EBO V	I (mA)	CBO max @ V max @ 25°C uA	hFE @ 2 mA	V_{CE} Sat @ 10 mA V	t on ns	t off ns	Outline
BE 107	Driver states of A F amplifiers, Signal processing Ccts, in T V and Low Power Low Speed Switchu	Metal	N	300	300	0 5	50	45	6	100	0 001	125-500	0 25	98	500	TO18
BC 108	Driver stages of AF amplifiers, Signal processing Ccts, in T.V and Low Power Low Speed Switching	Metal	N	300	300	0.5	30	20	5	100	0 001	125-900	0.25	98	500	TO18
BC 109	Low noise input stages of Tape recorders, hi fi equipment.	Metal	N	300	300	0 5	30	20	5	100	0 001	240-900	-	-	-	TO18
BC 147	Driver stages of A F amplifiers Signal processing Ccst., in T V , and Low Power Low Speed Switching	Plastic	N	220	300	0 45	50	45	6	100	0 02	125-500	0 25	98	500	MM10
BC 148	Driver stages of A.F amplifiers, Signal processing Ccts , in T V , and Low Power Low Speed Switching.	Plastic	N	220	300	0 45	30	20	5	100	0.02	125-900	0 25	98	500	MM10
BC 149	Low noise input stages of Tape recorders, hi-fi equipment.	Plastic	N	220	300	0 45	30	20	5	100	0 02	240-900	0 25	-	-	MM10
BC 177	Driver stages of AF amplifiers, Signal Processing Ccts , in T.V	Metal	P	300	130	0.5	50	45	5	100	0 002	75-260	-	-	-	TO18
BC 178	Driver stages of AF amplifiers, Signal processing Ccts , in T V.	Metal	P	300	130	0 5	30	25	5	100	0 002	75-500	-	-	-	TO18
BC 179	Low noise input stages of Tape recorders, hi-fi amplifiers, etc ,	Metal	P	300	130	0 5	25	20	5	100	0 002	125-500	-	-	-	TO18

TABLE 5

(BEL) High Frequency Silicon Transistors

Type No.	Application	Encapsulation	Structure P-PNP N-NPN	Max coll Diss. in free air at 25°C Pc (mW)	fT Mc	Derate in free air C/mW	Absolute max. rating @ 25°C BV CBO V	BV CEO V	BV EBO V	I_c (mA)	Typical h_{FE} @1mA	Outline
BF 194	A.M. Mix./Osc.I.F. amplifiers	Plastic	N	220	260	0 45	30	20	5	30	115	MM 10
BF 195	I.F. Amplifiers in A.M./F M receivers and input stages of car radios	Plastic	N	220	200	0 45	30	20	5	30	67	MM 10
BF 115	Broadcast and Television	Metal	N	145	230	0 9	50	30	5	30	115	TO 72
BF 184	AM./FM, IF amplifiers and gain controlled A.M input stages of mains receivers	Metal	N	145	300	0 9	30	20	5	30	115	TO 72
BF 185	Low noise AM/FM and Mix./ Osc. in portable receivers and car radios	Metal	N	145	220	0 9	30	20	5	30	67	TO 72
2N 929	Low level, low noise amplifiers up to 100 Mc	Metal	N	300	80	0 5	45	45	5	30	100-350 @10mA	TO 18
2N 930	Low level, low noise amplifiers up to 100 Mc	Metal	N	300	80	0.5	45	45	5	30	200-600 @ 10mA	TO 18

TABLE 6

(BEL) Germanium Low Frequency Transistors

Type No	Application	Structure P-PNP N-NPN	Max. Col. Diss in free air @25°C Pc(mw)	fT Mc	Derate in free air °C/mW	Absolute max ratings @ 25°C BV CBO V	BV CEO V	BV EBO V	I_C (mA)	I_{CBO} max @ V_{CB} max @ 25°C μA	Typical h_{FE} @2mA	Outline
AC 125	Pre-amplifiers and/or driver stages of A.F. stages	P	500	1 7	0 3	32	12	10	100	10	100	TO1
AC 126	Pre-amplifiers and/or driver stages of A.F stages	P	500	2 3	0 3	32	12	10	100	10	140	TO1
AC 127	As a complementary pair with AC 128 or AC 132 in Class B output stages	N	340	2 5	0 37	32	12	10	500	10	100	TO1
AC 128	Class A or Class B output stages	P	1 0W	1 5	0 29	32	16	10	1.0A	10	90	TO1
AC 132	Class B output stages as a matched pair and as a complementary with AC 127	P	500	2 0	0 3	32	12	10	200	10	135	TO1
AC 172	Low noise pre-amplifiers	N	200	2.5	0 37	32	12	10	10	10	45-110 @ 0 5mA	TO1
AC 187	As a complementary pair with AC 188 and class B output stages up to 3 W	N	800	5 0	0.29	25	15	10	1.0A	15	100-500	TO1
AC 188	As a complementary pair with AC 187 and class B output stages	P	800	1 5	0 29	25	15	10	1.0A	20	100-500	TO1
AD 149	Class B push-pull stages for powers up to 20 W	P	22.5W	0.5	-	50	30	20	3 5A	3mA	30-100 @ 1 0A	TO3

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(BEL) Germanium High Frequency Transistors

Type No	Application	Structure P-PNP N-NPN	Max. Col. Diss. in free air @25°C Pc(mw)	fT Mc	Derate in free air °C/mW	Absolute max ratings @ 25°C BV CBO V	BV CEO V	I_c (mA)	P G @ 100 Mc dB	I_{CBO} max @V_{CB} max @25°C µA	h_{FE} @1mA	Outl.
AF 114	R.F. Amplifiers up to 100 Mc.	P	75	75	0.6	32	15	10	13-20	1.2	150	TO
AF 115	R F Amplifiers and as Mix/Osc up to 27 Mc	P	75	75	0.6	32	15	10	10-20	1.2	150	TO
AF 116	I F Amplifiers a m /f m. and as mix /osc up to 16 Mc	P	75	75	0.6	32	15	10	8-20	1.2	150	TO
AF 117	IF. Amplifiers, r f amplifiers and mix/osc., in a m receivers up to 6 Mc	P	75	75	0.6	32	15	10	5-20	1.2	150	T(

TABLE 8

(SCL) Some More Transistors

Type No	Outline	PNP/ NPN	Absolute Maximum Ratings BV_{CBO} (V)	BV_{CER} (V)	BV_{EBO} (V)	I (A)	Maximum Collector Dissipation @T_c=25°C (W)	I Surge (A)	I_{cbo} Max (µA)	h_{FE} Min/Max	@ V_{CE} (V)	I_c (mA)
SF 103	TO-18	PNP	30	24	5.0	0.25	1.8	0.5	1.0	40/300	5	150
SG 103	TO-18	NPN	30	24	5.0	0.25	1.8	0.5	1.0	40/300	5	150
SK 100	TO-5	PNP	60	50	6.0	0.50	4.0	1.0	1.0	40/300	5	150
SK 101	TO-5	PNP	40	30	5.0	0.50	4.0	1.0	1.0	40/300	5	150
SK 102	TO-5	PNP	30	30	3.5	1.00	3.0	1.5	1.0	50/280	5	500
SL 100	TO-5	NPN	60	50	6.0	0.50	4.0	1.0	1.0	40/300	5	150
SL 101	TO-5	NPN	40	30	5.0	0.50	4.0	1.0	1.0	40/300	5	150
SL 102	TO-5	NPN	30	30	3.5	1.00	3.0	1.5	1.0	50/280	5	500